LATHES

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LATHES:

THEIR CONSTRUCTION AND OPERATION

BY

GEORGE W. BURLEY, WH.EX., A.M.I.MECH.E.

LECTURER IN ENGINEERING AND THEORY AND PRACTICE OF MACHINE TOOLS IN THE UNIVERSITY OF SHEFFIELD

WITH TWO HUNDRED ILLUSTRATIONS

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PREFACE

This book has been written with the object of presenting a survey of the whole field of lathe construction and operation from the descriptive point of view. Owing to the exigencies of space and the extensiveness of the field, however, it has not been found possible to deal comprehensively with every possible aspect, though the points of greatest importance have been dealt with at some length.

It is hoped that the book will prove useful to engineering students and apprentices, and even maturer persons who desire to obtain a knowledge of lathe possibilities.

All the lathes described are modern, the thanks of the Author being due to all the firms, whose names are mentioned in the text, who have willingly provided him with either photographs or blocks of their specialities.

GEORGE W. BURLEY.

SHEFFIELD UNIVERSITY,
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CONTENTS

CHAPTER VI

CHAPTER VII

CHAPTER VIII

CHAPTER IX

CHAPTER X

CHAPTER XI

CHAPTER XII

APPENDIX

GLOSSARY OF TERMS USED IN THE BOOK

Archimedian spiral = a curve formed by the combination of a rotatory and a rectilinear motion on a plane surface, the motions being referred to the same point or pole and having a relation which is arithmetically progressive.

Back-gear ratio = the ratio of spindle speeds of a lathe with and without the back-gearing in action.

Capstan = a four or five-armed wheel.

Chaser = a tool with a serrated cutting-edge for originating and finishing screw threads.

Chuck = a revolving vise attached to the driving spindle.

Chuck-plate = the connexion between the chuck and the driving spindle.

Copy or Master Screw = a lead screw for screw-thread cutting without the use of change gears.

Copy Die = the element which works on the copy screw.

Driver = any element whereby motion is transmitted to work which has to be machined in the lathe.

Driving or Catch-plate = a plate which is screwed on the nose of the driving spindle to transmit motion through a carrier or dog.

Face plate = a plate, usually of fairly large diameter, attached to the driving spindle, on which work is bolted.

Gib = a strip fitted between guiding and sliding faces for purposes of adjustment of nt.

Helix = a curve formed by tracing a straight oblique line round a cylinder; sometimes, though wrongly, described as a spiral.

Mandrel = an element on which work is carried; the spindle of a loose-headstock.

Saddle or Carriage = the lower part of a slide-rest.

Slide-rest feed-apron = the plate at the front of a compound slide-rest which carries and covers the gear-wheels between the lead-screw and feed-rod and the slide-screws.

Sliding feed = the movement on a compound slide-rest parallel to the length of the bed.

Surfacing feed = the movement normal to the length of the bed.

Shears = the tops or ways of a lathe bed, these being used for the support and guidance of the headstocks and slide-rest.

Turret = a machine-tool element capable of being swivelled or rotated about an axis (usually vertical or horizontal), and in which four, five, or six tools are placed uniformly.

CHAPTER I.

INTRODUCTION.

ONE of the most prominent features of the present age is to be found in the fact that we are almost entirely dependent upon the machine and mechanical processes for the majority of the things that we have come to regard as necessities of our daily life. It is quite true that handicraft processes still exist, but, from the point of view of production, they are of secondary importance when compared with mechanical processes. Now, though it is not probably realized by more than a comparative few, the machine tool (as it has come to be known, though such a description is a misnomer since it is really a tooling machine, and not merely a tool) is quite as important as the machine which ministers directly to our daily needs, since it is by means of the former that the latter is made. Furthermore, the developments of machines and mechanical processes generally appear to have synchronized with those of machine-tool design and construction, though it may be that, in practically every case, the demand for improved methods of manufacture and greater accuracy in mechanical production has inspired and produced the improvement in the general design of machine tools which has been so marked of late years.

Now, the true function of a machine tool is the production of parts of required sizes and shapes from stock by the removal of the excess material. This excess material, after its removal, is rejected as waste or scrap, and the removal is effected by means of one or more cutting tools which accomplish this either by a scraping or wedging or shearing action. In other machines, such as the power and other hammers, which work stock to required sizes and shapes, the transformation is usually effected by means of a combination of compressive and stretching forces suitably applied, the object being to transfer material from one part of the stock to another in order to attain the required object.

Of all the many varieties of machine tools extant at the present time, the lathe is undoubtedly the oldest as well as the commonest, its numbers far exceeding those of any of the others. It is the time-honoured veteran of the machine shop, and has, in some of its more or less modified forms, been the precursor of quite a host of other machine tools, though probably the connexion between these latter and the lathe is not very clear in view of modern developments, especially in the direction of specialized design. Hence, it is not unreasonable to regard the lathe as the premier machine tool, although its relative importance is not now quite as great as it was in the early days of machine-tool design.

Machine tools generally may be divided into two well defined classes, namely, those in which one or more tools, each having a single cutting edge, are employed, and those in which the cutter or tool has two or more cutting edges. The lathe belongs to

the first class, and is distinguished from other members of that class by the relation which subsists between the work which is operated upon and the cutting tool. In the lathe the work has a rotatory motion about a fixed axis, the relative motion necessary between the work axis and the tool being obtained by giving a movement to the tool in a direction either parallel to, normal to, or inclined to the axis of the work. This applies in practically every case, whether the surface to be tooled is external or internal, cylindrical, conical, plane, or helical. In other machine tools the prevailing conditions are always different from these, either in regard to the motion of the work, or in regard to the motion of the cutting tool.

CHAPTER II.

EVOLUTION OF THE LATHE.

If the records of history are to be relied upon there can be little or no room for doubting that man from the birth of the earliest civilizations has been acquainted with handicraft tools, by means of which he has been able to shape substances to suit his various needs and whims. In the earliest ages, doubtless, his tools were exceedingly crude, and it is really remarkable that he was able to produce the work which he is reputed to have done. As he progressed from plane to plane of development, he was however, able to improve his tools in certain notable ways, though for many centuries his tools were purely handicraft tools, and no mechanical aid was either sought or obtainable until the idea of the primitive lathe was conceived.

It is reasonable to suppose that the first application of the idea of shaping or forming substances by turning or rotating them was made by the potter on the so-called "potter's wheel," when, in the early stages of civilization, he attempted to produce vases and other round vessels of clay, though in this case the substances which had to be worked were always in a more or less plastic condition. It was then probably but a step forward to apply this idea or

principle to the case of shaping harder materials, such as wood, ivory, and bone, when man had discovered how to make tools which would cut these substances.

Between these two cases there appears to have been a distinguishing difference: in the former case, the axis of the wheel was vertical, whilst in the latter case the axis of the material operated upon was horizontal or nearly so, and this it has remained up to the present time, with but one exception.

The exact origin of the lathe is wrapped up in the obscurity of antiquity, but it is generally supposed that it was invented at least 3000 years ago. Several claims for its invention have been made on behalf of people in different countries and at different times, but it is quite impossible to give the credit to any one man. Suffice it to say that the discovery marked a new era in the mechanic arts.

The earliest lathes of which we have any reliable knowledge were, naturally very crude. They were dead centre lathes and embodied a principle of design, namely two dead or non-rotating centres, which is found in only one or two cases amongst modern lathes, though in the East the native lathes of to-day do not apparently differ in any substantial manner from the primitive lathe.

In its most primitive form the lathe consisted of two wooden posts or stakes which were driven into the ground and fixed therein in an upright or vertical position. On the inside of each post at a short distance from the ground a pointed pin or conical centre, made of wood or some similar material, projected, this being fixed to or in the post in each case, so that

no motion whatever was imparted to it. The two centres were placed at approximately the same distance from the ground so that the line joining the points was horizontal or nearly so. On these points the work was supported and pivoted (the work having been previously centred at each end though more or less crudely), and any tightness or slackness of the work between the centres was removed by the adjustment of the position of one of the posts.

To the posts a horizontal beam was temporarily attached on the front of the lathe, and this served as a support or rest for the cutting tool, in the manipulation of which the turner (who was almost invariably of the itinerant class) was usually adept.

The motion of the work was not of the uni-directional type, which is characteristic of the majority of modern lathes, but was of the oscillatory or to-and-fro rotatory type, the work making a few revolutions first in one direction, then in the other, this cycle of changes being repeated more or less indefinitely. These two motions were imparted to the work (which had previously been made approximately round at one end by hand) by means of a cord, or its equivalent, which was wrapped once or twice round that end, one end of the cord being attached to a foot of the turner or his assistant, and the other held in his hand. The cord was pulled to-and-fro, first by hand, then by foot, this action causing the cord to be wrapped on and off the work simultaneously, and the work to revolve in each direction alternately. Obviously, actual cutting was possible only during the period of the forward movement, the turner having to keep his tool withdrawn slightly during the other

period, the duration of which was roughly equal to that of the former. When the turner (who in the very early days invariably sat on the ground) himself actuated the cord and work, he had to use a hand and a foot to manipulate the tool; when he had an assistant, however, he was able to use both his hands to control and guide the tool.

With such a lathe as this, it cannot reasonably be supposed that the work produced thereon was at all comparable with that produced on the modern lathe. We must, however, appreciate the fact that by means of it greater accuracy of work was possible than by any other method then known. In fact, we are told that the ancients commonly observed that when anything was done accurately and delicately, it was "as if it had been turned in the lathe".

The first step in the evolution of the lathe was the raising of the axis, thus allowing the turner to occupy a standing position in contradistinction to the sitting posture which is so characteristically Oriental. This change was probably due to the spread of the use of the lathe to Western Europe.

The method of holding and driving the work, however, remained the same until the use of the spring pole or elastic *lath* (from which the name *lathe* is probably derived) was conceived in connexion with the method of driving. The spring pole was usually a young sapling which possessed a large amount of resiliency or inherent elasticity, and which had its upper end bent over slightly. It was placed in the ground in close proximity to the lathe, so that its upper end was immediately above one end of the work. To this end of the pole one end of the

cord was fastened, the other end, as before, being attached, to the foot of the turner or his attendant. The cutting motion was obtained by pressing the foot down, and the return motion resulted from the effort of the pole to return to its normal position when the pressure of the foot was removed. During each movement the cord was kept just taut on the following side.

The next stage in the development of the lathe was the introduction of the treadle. This was made shortly after the spring pole or lath had been adopted (apparently about the sixteenth century), the lower end of the cord being attached to the treadle, and the latter being actuated by the foot of the operator. This was a decided improvement, but the bi-directional motion of the work was still retained.

A change in the form of the bed of the lathe also occurred, the new form consisting of two beams of wood separated by short distance pieces, and tied together so as to be parallel. These were secured and supported on two wooden legs or posts or on a bench-like structure. Centre posts were provided, and these had tenons formed on their undersides and passing through the space between the wooden beams or bearers, with wedges placed in them to hold the heads or posts in position. Later, the head on the left became fixed and only the one on the right could have its position altered to allow for differences in the lengths of the various pieces of work.

A variation of the spring pole or elastic lath in the bow of the archer, or its equivalent, appears to have been adopted in certain countries during the seventeenth century. A lathe embodying this idea is illus-

trated in Fig. 1. In this form of lathe, the frame of the bow was secured to a fixture either above or behind the lathe, and the actuating cord had one end attached to the middle point of the bow-string. The action was precisely the same as that which occurred

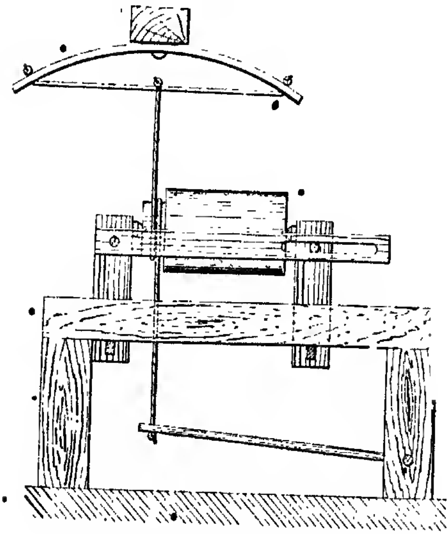


FIG. 1.—Early form of lathe.

in the case of the pole lathe, the restoring force being due to the elasticity of the frame of the bow.

It was about this time that the idea of the wheel-drive was applied to the lathe to give a uni-directional motion to the work, the two centres still both being kept dead. This drive does not appear to

have been adopted as a rival to the older drive, as in many cases the wheel drive and the bow or pole drive existed side by side. The wheels which, as one would naturally suppose, were made of wood, built up and of crude design, were placed in various positions with respect to the lathe, but in every instance there was present the germ of the modern treadle lathe. The wheel was mounted on a wooden shaft which rotated in wooden bearings, the latter, obviously, offering a considerable amount of frictional resistance and, therefore, heating excessively. The crank pin was made of wood, and this was connected to the treadle by means of a strap or thong of skin or leather. The drive from the wheel to the work was direct, though where the work was small in diameter a pulley, encircling the work, was employed, this pulley being driven from the wheel by the cord or rope.

The dead-centre form of lathe was not suitable, as it stood, for internal or cupped work. To make it suitable for such work it was necessary to remove one of the posts or heads (the one equivalent to the loose headstock of the modern lathe), and to substitute in its place a post or head in which the outer end of the work could be placed.

From this, doubtless, the running mandrel or spindle was developed, it requiring but a slight change to use a wooden mandrel running in two heads or posts, and to secure the work to the nose or projecting end of this, the outer end of the work being, as before, supported on the centre in the tail-post. In the early forms of mandrel lathe both the uni-directional and oscillatory motions were used.

The next step was in the substitution of iron mandrels for the existing wooden ones in the mandrel lathes, and in the use of iron centres in the dead-centre lathes. Following these was the use of tin and lead bearings, these being fitted in the wooden posts of the driving head, which were each secured to the bearers of the bed separately by means of wedges. These were tremendous advances in those days, the result being increased accuracy of work.

The bar rest for the tool was next changed for the movable tool rest wedged to the bed, but this change was a very gradual one indeed, since right into the middle of the nineteenth century the bar rest was used in conjunction with the dead-centre lathe.

An improvement in the form of the tailstock was made in the replacing of the fixed centre by a nut and screw, the end of the screw being sharp pointed like the end of the modern centre. The centre was adjusted by turning the nut on the screw, the latter being fitted in the wooden head, and the nut placed on the front or work side.

Metal headstocks were then substituted for the wooden ones, the first metal headstock being constructed by Holtzapffel in the closing years of the eighteenth century. This headstock was made in brass though iron headstocks were made shortly afterwards. Conical spindle or mandrel journals and bearings were also applied to the lathe, though this idea was not exactly new since conical journals and bearings in wood had been tried more than 100 years previously. This was, however, the first really successful attempt to take up the thrust on a conical bearing surface.

At first only the driving headstock was made in metal, but, later, the tailstock was treated in the same manner, though only for mandrel lathes, the hand-turning dead-centre lathes retaining to the last the two wooden heads.

The method of holding down the heads and the tool rest was also improved upon in some cases, a bolt and nut being used in a manner somewhat similar to the present-day English method on hand-turning lathes. A method in which the bolt and wedge methods are combined is much used on wood-turning lathes even to-day, a hanging bolt and nut being made rigid by the driving-in of a wooden wedge between the head of the bolt and the underside of the lathe bed, which is usually (though not always) made of wooden beams or bearers.

An epoch-marking event in the history of the lathe occurred when Maudsley in the early part of the last century invented the slide rest. Hitherto all turning operations had been hand operations, but by means of the slide-rest and the guiding or leading screw (which he also applied to the lathe, he being the first to make a fairly large accurate screw) operations could be made by means of a power-fed tool. Without this invention, the lathe would have remained a hand-turning machine, and many of the present machine-tool developments would have been post-dated.

The form of the lathe bed also underwent changes. With the advent of the metal headstock it was found that the wooden bearers or shears did not possess good wearing qualities, to remedy which, at first, the tops or ways were plated with sheet metal secured

by screws. An improvement upon this was the use of cast-iron strips running the whole length of the bed (one on each shear), these supporting both headstocks and guiding the tailstock. These strips had curved upper faces (as shown in Fig. 2), there

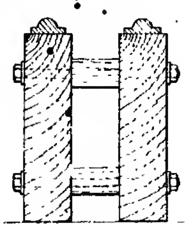
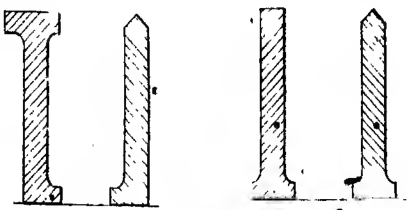


FIG. 2.—Early lathe bed.

FIG. 3 Maudsley bed.

being corresponding grooves in the undersides of the two headstocks.

With the advent of the slide-rest the use of the metal bed became necessary. Maudsley used a bed of triangular section (Fig. 3) on his first self-acting



FIGS. 4 and 5.- Sections of cast-iron beds.

lathe, there being two of these sections used side by side. Beds of sections similar to those indicated in Figs. 4 and 5 were also employed, and it is from

these that the modern lathe beds of both English and American designs have been evolved.

Cast iron beds were also used in hand-turning lathes of the mandrel type, though up to the middle of the last century wooden bearers were in common use even for metal turning.

The remaining stages in the evolution of the lathe belong to what may be conveniently termed the era of modern machine-tool design, the main features of which, so far as the lathe is concerned, will be dealt with in the succeeding chapters.

CHAPTER III.

CLASSIFICATION OF MODERN LATHES

THE tendency of modern machine-tool practice is in the direction of specialization and with no machine-tool is this tendency more definite or more extensive than with the lathe. The demand for the reduction of the cost of production as the direct result of an increase in the rate of production has caused such a multiplication of lathe forms that, at the present time, their number is somewhere in the neighbourhood of fifty, and many of these are manufactured in a wide range of sizes. Many of these variants can, however, be classed together since they embody practically the same general principles of design and operation and vary only in particular details.

An approximate classification of the principal lathe types may be made as follows.

1. *Hand-turning Lathes.*—These are, in the main lathes of a comparatively small size, and they are so designed and constructed that all operations on them have to be performed, either directly or indirectly, by hand. In the former case hand tools are employed, these being held in position on tool rests or supports; in the latter case, tools are held in either a simple or compound tool rest which is secured rigidly on the bed of the lathe, the required

motion being imparted to the tool by the hand-operation of either or both of the slide feed-screws. Lathes of this type comprise, amongst others, bench, precision, model, pattern-makers', wood-turners', plain turning, ornamental turning, and some forms of brass-finishing lathes. The characteristic feature of such lathes is to be found in the fact that no movement is of the self-acting or automatic variety. The lathes may be either power- or treadle-driven.

2. *Engine Lathes.*—This class is a fairly extensive one, and is the one to which the majority of general utility lathes belong, as well as a number which are more or less restricted in regard to range of usefulness. Strictly, an engine lathe is one which is provided with power-actuated tool feeds for sliding (that is, longitudinal traversing), surfacing (that is, transverse traversing), and screw-cutting, but the description as a generic one may be applied to practically all so-called centre lathes provided that they are provided with at least one self-acting feed motion. Hence, there may be included in this class lathes which are distinguished from one another by having either only a self-acting sliding feed motion, or only sliding and surfacing (as in some boring and surfacing lathes), or only sliding and screw-cutting, on only screw-cutting and surfacing. In this class there may also be included such lathes as front-slide lathes, chucking lathes, and gap-bed lathes (which are essentially English). Engine lathes are usually power-driven, though some of the smaller sizes are either also or only provided with a treadle attachment.

3. *Turret Lathes.*—These are lathes which are characterized by the possession of a turret head, in which the tools are held in such a way that each tool in its turn is brought into its working position as the result of the rotation of the head. They may be either non-automatic, semi-automatic, or full-automatic. The first is the ordinary form of turret lathe, whilst the last is a special machine which is known in one form as an automatic screw machine. Further, non-automatic machines may be either plain turret lathes (in which the turret head is rotated and translated by means of a straight handle or lever) or capstan lathes (in which a capstan handle with either four or six arms replaces the straight handle). There are several other forms of this type of lathe, but of these the most important is the combination turret lathe. In this machine a turret head is combined with an ordinary engine-lathe slide-rest or a slight modification of it. In some few cases the turret head has to be rotated by hand; but in the majority of cases this action is automatic.

4. *Vertical Lathes.*—These are also known as vertical boring and turning mills, and are distinguished from all other lathe-forms by the fact that the axis of the work is invariably disposed in a vertical position. Both internal and external work can be performed on these machines, which are more suitable for large-diameter work of short length than any other form of lathe. They may have either one, two, three, or four tools at work simultaneously, and the tools may be secured in plain or turret heads.

5. *Special Lathes.*—This is a very numerous

class and includes the following: lathes for axle-turning, shaft-turning, fly-wheel and pulley turning, and wheel bossing and boring; lathes for chucking, taper-turning, roll-turning, chasing, screwing, forming, copying, backing-off, and relieving; lathes for spinning, polishing, and grinding; face-plate or pit lathes; crank-shaft lathes; crank-pin-turning lathes; automatic threading lathes; pin-and-stud-turning lathes; nut-facing lathes; projectile-turning lathes; and lathes with double and open spindles.

CHAPTER IV.

HAND-TURNING LATHES.

ALL hand-turning lathes have four essential elements: the fast or driving headstock, by means of which the power and motion are transmitted to the work; the loose-headstock or poppet-head by means of which the tail end of the work is supported when necessary; the tool rest; and the bed on which the above three parts are mounted and on which the two latter are capable of sliding when any change or adjustment of position is required.

Metal-turning Lathes.—The beds of lathes of this type are usually of the flat-top variety, the standard form being represented in section in Fig. 6. These beds (which are made of cast-iron of a high-grade) are almost invariably mounted on legs or standards which are, or should be, secured firmly to the floor or foundation on which the lathe stands. The American hand-turning

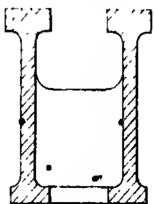


Fig. 6.—Lathe bed.

lathe bed has a top with raised or inverted vees (one on each shear or girder section), these acting as guides to the loose headstock, whereas in the case of

the English bed this guidance is obtained by means of a tongue or ward on the underside of the stock which fits exactly in the space between the two shears.

One form of this type of lathe is indicated in Fig.

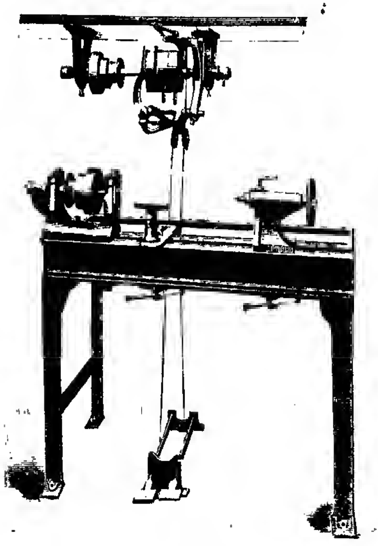


FIG. 7.--Metal hand-turning lathe.

7. It is a power-driven lathe, this being the modern form of the hand-turning lathe. Treadle or foot-driven hand-turning lathes are very rarely met with nowadays, the great weakness of such lathes being that it is impossible to perform the two simultaneous operations of driving and turning in a satisfactory manner. The power is transmitted from a main-

driving or line shaft by means of two belts to a countershaft or overhead gear which is part of the equipment of the lathe. This countershaft is provided with fast and loose pulleys, there being one fast pulley and two loose ones. When the lathe is not in commission, the two belts (one of which is crossed so as to give reversal of motion when required) run on the two loose pulleys. To put either belt into action it is necessary to move it on to the fast or driving pulley of the countershaft. This movement is effected by means of a belt shifter, which (in this case) consists of two forks connected to two foot levers by either chains, rope, or cables. When either foot lever is depressed, the belt fork connected to it is caused to move towards the fast pulley so as to occupy a position directly opposite to it. On the release of the lever (which can be held in position by means of a notch) the belt fork moves back to the loose pulley carrying the belt with it. Other designs of belt-shifting gear are applicable in cases of this kind, but in all instances it should be impossible to have both belts moving towards the driving or fast pulley simultaneously.

Speed-variation is made possible by the provision of a pair of three-stepped cone pulleys, one on the countershaft and the other (which is, of course, reversed) on the spindle of the driving headstock. The countershaft is supported in bearings in two hangers, either (generally) of the U or J type, these being secured to the roof girders or beams.

The spindle of the driving headstock is usually provided with two journals, the necks of which may be either parallel or conical; in the case of the for-

mer the bearings are in two parts, and are not adjustable; in the case of the latter the bearings are generally (though not invariably) of the adjustable variety. In this type of lathe usually a pin or pivot thrust bearing is provided at the tail end of the spindle to take the thrust on the spindle which is produced in the cutting operation when the direction of cutting is towards the driving headstock, though a ball thrust-bearing is to be found on some of the higher grade machines. The use of the latter is preferable to the use of the former, and gives far less trouble in regard to heating and adjustment.

In all modern lathes which have any pretension to the name, the driving-headstock spindles are made of high-grade crucible cast steel, and in some cases these are hardened throughout, whilst in others only the journal necks are hardened. In any case the journal necks are ground to shape and size. In regard to the bearings, cast-iron, brass, high-grade phosphor-bronze, and anti-friction metal are all in use. The nose of the spindle may be threaded either externally or internally, or both.

The driving headstock is secured to the bed by means of clamping bolts, plates, and nuts, the exact position of the head being located by the use of a tongue on the underside of the stock which fits in the space between the two shears of the bed.

The loose-headstock (movable headstock, poppet head, or tailstock, as it is variously called) carries the supporting centre for the tail end of the work. The centre is fitted in the end of a hollow horizontal spindle (called the mandrel of the headstock), the position of this in the headstock being adjusted by

means of either a lever, a handwheel and screw, or both. In the loose-headstock which is represented in Fig. 7, it is the second of these methods which is employed. Incidentally, it may be remarked that this method is the commonest of the three. The body of the headstock is clamped in position on the bed of the lathe by a handle and plate as shown in the figure.

The hand tool rest consists of a slotted base, which rests on the lathe bed, and a top tee-piece which fits in a boss springing from the base. The tee-piece (which should be made of cast steel) can be secured in any position by means of a set-screw in the base. For brass-turning and chasing the top of the rest need not be very wide but for iron and steel turning it is very desirable to have a flat top, as this gives more support for the heel of the turning tool. This difference is due, more than to anything else, to the difference in the cutting forces which exist in the cases of the two different classes of metals. The base of the rest may be clamped in any position in the manner indicated, though there are more elaborate and expeditious methods in use.

Some hand-turning lathes for metals are also equipped with a slide-rest. This is usually of the compound type and fitted with two slides, one (the lower) being disposed across the bed and the other normally parallel to the length of the bed. A further improvement is the substitution of a swivelling top slide for one that is fixed; then the top slide may be arranged at any angle to the lathe axis and so used for the machining of tapers. This form of slide rest cannot, however, be traversed along

when the actual operation of turning is in progress, but is secured rigidly to the bed, usually by means of clamping bolts, plates, and nuts in the orthodox manner; that is to say, it is *not self-acting.*

Wood-turning Lathes.—These differ in general from hand lathes which are designed for metal turn-

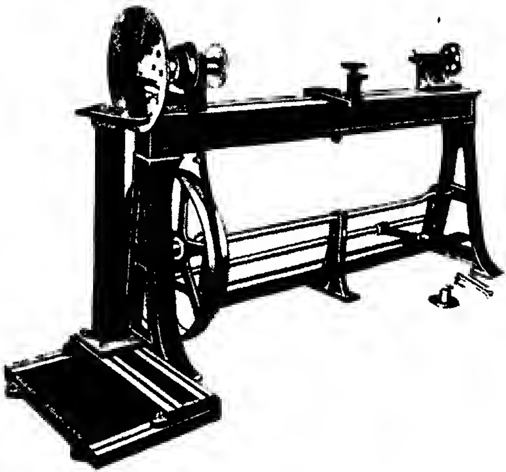


FIG. 8.—Duplex wood-turning lathe.

ing, although it is possible to turn metal on wood-turning lathes, and wood on metal-turning lathes It is, however, desirable to keep the two forms distinct.

In the first place, since cutting speeds are generally much greater for wood than for the metals, the available spindle speeds (in revolutions per minute) are higher for wood-turning lathes than for the others.

Again, the beds of many lathes of this kind are made of wooden bearers, in design and arrangement somewhat similar to those of the early lathe, as illustrated in Fig. 2, but without the added metal guides; in this form the bed is sometimes known as a "gantry".

An up-to-date form of plain wood-turning lathe is represented in Fig. 8. It will be seen that this is a treadle or foot-driven lathe with a bed which is longer than that of the average wood-turning lathe of the same centre-height. In this lathe the two ends of the spindle are utilized, the outer end being available for use when work of a diameter larger than that which can be worked over the bed has to be turned. Two tool rests are, therefore, provided, one resting on the bed proper, and the other on an auxiliary bed which is so designed that the rest can be moved in either or both of two directions at right angles to each other. This lathe is manufactured by Mr. Milnes, of Bradford.

Drivers.—In connexion with the operation of metal-turning lathes, the ordinary methods of driving the work, namely, the chuck, face plate, and catch-plate methods, are available; on wood-turning lathes, the face-plate, chuck, and special driver methods are employed.

CHAPTER V.

ENGINE LATHES.

THIS class of lathes may be divided into sub-sections in several ways: thus they may be divided into treadle and power lathes, according to the manner in which they are driven; or into small, medium, and large lathes, according to their size; or into carbon, "compromise," and high-speed lathes,[1] according to the design of the speed-arrangements and to the weight relative to the capacity or size of the lathe. Again, engine lathes are either belt or motor-driven and the former are provided with cone-pulleys and variable-speed belts or "all-gear" driving headstocks and constant-speed belts.

The Lathe Bed.—The forces which are exerted upon the bed of an ordinary engine lathe are chiefly bending and twisting forces due to the cutting. The ideal form of bed to resist these (especially the latter) is undoubtedly the closed or box-section form. This, however, in the majority of cases is difficult to apply, and compromise forms of beds have to be adopted.

The standard form of lathe bed in use in this country for small lathes is indicated in Fig. 9. The tops or ways of the shears are flat, the outside faces

[1] This method is due to the late Dr. Nicolson and to Mr. Dempster Smith.

are inclined (usually at an angle of from 45° or 60° to the horizontal, the standard angle being 55°, which is, of course, the profile or section angle of the British Standard Whitworth screw-thread) to guide the slide-rest, and the inside faces are vertical to guide the movable headstock and to assist in the alignment of the fixed headstock. In some forms the outside faces are vertical and not inclined. The beds of large lathes have three tops or ways usually, and the girder sections are of the box pattern, as is shown in Fig. 10.

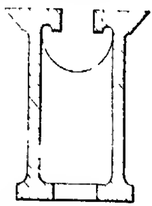


FIG. 9.—English lathe bed.

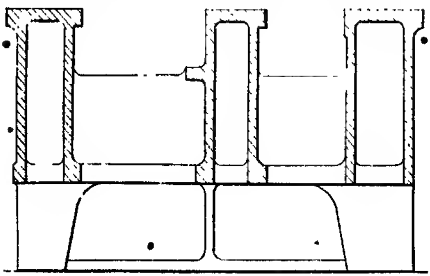


FIG. 10.—Bed for large lathe.

Modifications of this form of bed are very numerous, and include beds which are provided with tee-slots in the shears for the purpose of guiding both the slide-rest and the loose headstock, and also beds of the double-tier type.

In every case cross-girts or ribs (sometimes of

box section) are cast between the girder sections to strengthen the bed, especially in regard to torsion.

The standard American form of lathe bed is represented in Fig. 11. The raised inverted vees (having an angle of 90°) on the tops of the two shears differentiate it from the above. This form is really one of the original forms of the cast-iron lathe bed, and was discarded many years ago by lathe designers in England, who preferred the more substantial form with the flat tops. Except on the heaviest lathes, and in one or two special cases of small lathes, this form or a modification of it has been adopted universally in America.

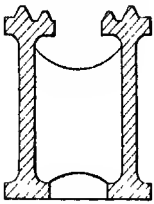


FIG. 11.—American lathe bed.

Where four vees are employed, the two outer ones serve as guides to the slide-rest, and the two inner ones as guides to the loose-headstock. The two latter are also used in connexion with the alignment of the fast headstock. Modifications of this form involve the elimination of either one or two of these vees, but, generally, at least one vee is retained to serve as a guide to each sliding element.

So-called Anglo-American lathes are almost invariably provided with vee'd beds.

The beds of German lathes generally combine the features of American beds with some of those of English beds, though there are some notable exceptions to this. One form of lathe bed (the Pittler) is depicted in Fig. 12. Its characteristic features

are strength and rigidity accompanied by very wide bearing and guide surfaces.

English lathe design is also distinguished from American by the fact that all American lathe beds are "straight" (that is, with a uniform section from the driving headstock to the other end), whereas many English lathes have gap beds, and are therefore available for use when short work of a diameter considerably greater than that indicated by the height of the centres has to be machined. With gap lathes gap pieces or bridges are provided for insertion in the gap when it is desired to feed the slide-rest close up to the driving-headstock. In some cases only half-gap pieces are provided.

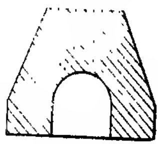


FIG. 12. German lathe bed.

Lathe-bed Standards.—The beds of lathes are supported in at least three different ways. In the case of small engine lathes—and this it may be stated incidentally applies also to hand-turning lathes—the bed rests on two leg standards, the legs being either straight (as indicated in Fig. 7) or more or less curved (as shown in some of the succeeding illustrations). The two standards are in the majority of cases situated at the extreme ends of the bed, the exceptions to this rule being comparatively rare. For medium-sized lathes the leg standards are replaced by box or cabinet standards, these providing a much more substantial support to the bed. In some few instances the standard at the driving-headstock end is placed not at the extreme end of the bed, but at some distance towards the other end

so that the support is then almost under the centre of the driving headstock. This practice, it is claimed, reduces the twisting and bending stresses induced in the bed. The third method is the one which is adopted on all large and heavy lathes. In this case the bed rests solidly on the floor or foundation, there being no intermediate support. This method is, of course, the only suitable one for lathes of this class, since the distance between the lathe axis and the floor is made as nearly 3′ 6″ as possible.

The number of points of contact or support on the floor or foundation varies with the size of the lathe. Small lathes have usually four such points, and it is common English practice to bolt the legs down securely to the floor or foundation at each of these points after the lathe bed has been levelled up. American practice in this respect is rather variable, some engineers not bolting the lathes down securely, but leaving them with a greater or less amount of flexibility in regard to adaptation to prevailing conditions. Large lathes have generally more points of support and larger contact surfaces between the feet and the foundation. Prof. Sweet is credited with having adopted the plan of having a three-point support, one of the legs being secured at two points to the foundation, whilst the other is left to accommodate itself to the conditions of cutting, etc. The second leg is really a floating leg. It is, of course, contrary to English practice to adopt anything of this kind, since English practice in connexion with machine tools connotes rigidity and stability.

The Driving or Fast Headstock.—This, speaking generally, is of three types, namely, the cone-pulley

headstock, the single-pulley geared headstock, and the motor-driven geared headstock. The three types are distinguished from one another by the methods adopted to obtain the speed changes which are so necessary in engine-lathe work in which the diameters of the stock may vary between very wide limits and in which the cutting speeds may also—and usually do—vary considerably.

An example of a lathe provided with a cone-pulley headstock is to be found in the Selson lathe which is shown in Fig. 13. It is equipped with a cone-pulley driving headstock having three steps or diameters, on any one of which the driving belt may run. The cone-pulley is generally mounted on the main or driving spindle, but it is arranged so that there is relative rotatory motion possible between the two when the lathe is provided with back-gearing, as is usual. Secured to the spindle between the front headstock bearing and the cone-pulley is a large toothed wheel, and it is to this that the cone-pulley is fastened (either by means of a locking bolt or a spring pin), for the direct drive to the spindle. To increase the available number of spindle speeds (in revolutions per minute), the use of back-gearing is resorted to. The simplest form is the compound or double back-gearing. In this, the speed is reduced by undergoing two distinct changes through two sets of gears. The first set comprises a spur pinion which is keyed, or secured in some other way, to the small end of the cone pulley (and, therefore, known as the "cone pinion") and a larger wheel on the back-gear shaft immediately opposite the pinion. This large wheel is connected to

another pinion in any one of several possible ways,

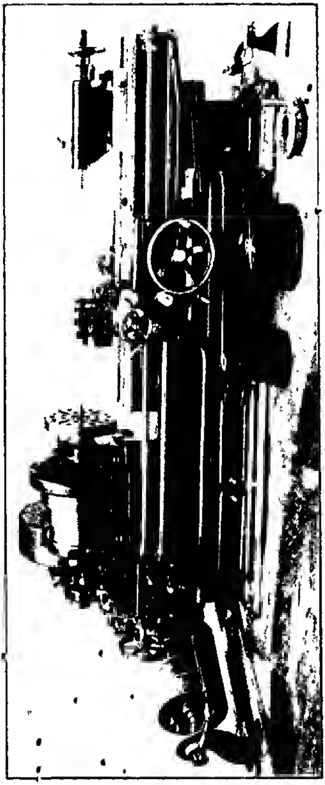


FIG. 13.—Selson engine lathe.

this pinion being disposed immediately behind the large driving gear wheel on the spindle. The back-

gear shaft on which the first wheel and the second pinion are mounted is usually of the eccentric type, thus allowing its wheel and pinion to be moved away from or towards the driving spindle, and being disengaged from or engaged with the other pinion and wheel. When the back-gear is in action the cone-pulley and the main gear wheel must not be locked together. The gear ratios in common use for double gearing vary from 3 : 1 to 24 : 1.

It has been the common English practice until recently to make the four gear wheels of the same widths and pitches. This is not scientifically correct, since the latter two have to carry a larger load than have the former two owing to the reduced linear speed. American practice has nearly always been to make the latter two gears wider and of a coarser pitch than the other two, and this is general practice everywhere now.

All machine-tool spindle speeds are arranged in geometrical progression (that is, there is constant ratio between each speed and the next highest or lowest speed), or as nearly as possible. For lathes, the value of the common ratio varies from 1·1 : 1 to 2·0 : 1, the following being average values:—

English	Practice . .	1·25 : 1
American	,, ...	1·40 : 1
German	,, . . .	1·50 : 1.

To obtain this regular succession of speeds the diameters of the cone-pulley steps have to be carefully calculated and related exactly to the back-gear ratio, which is always an intrinsic part of the design of the speed arrangements. When two countershaft speeds are in use, then they also are involved in the design.

It will readily be observed that the number of spindle speeds available is multiplied by 2 by the introduction of double back gearing, and again by 2 when another countershaft speed is added. Thus, if the cone-pulley is provided with, say, 4 steps or diameters, then, with 2 countershaft speeds and one arrangement of double back-gearing, the number of spindle speeds available is 16, a number which is more than sufficient for ordinary practice.

Numerous modifications and extensions of the above arrangements of the back-gearing have from time to time been proposed and applied. Of these only one or two will be mentioned here. One method involves the use of an additional cone-pinion and engaging gear wheel on the back-gear shaft, this latter being connected rigidly to the other gear wheel and so designed that both wheels may be moved on a feather in the back-shaft sleeve, thus causing one wheel to be engaged with its pinion and the other to be disengaged at the same time. This alteration adds *sc* speeds to the number of spindle speeds, *s* being the number of steps on the cone-pulley, and *c* the number of countershaft speeds, which is never greater than 2. Another method involves the use of treble or triple gearing (that is, with three sets of gear wheels) and quadruple gearing (that is, with four sets of gear wheels), but such arrangements are seldom found on lathes other than those having a direct face-plate drive. Triple-gear ratios vary from 19 : 1 to 40 : 1, and quadruple from 36 : 1 to 70 : 1. In another method epicyclic bevel gearing is employed.

The cone-pulley headstock possesses the disad-

vantage of using a belt which at the bottom end of

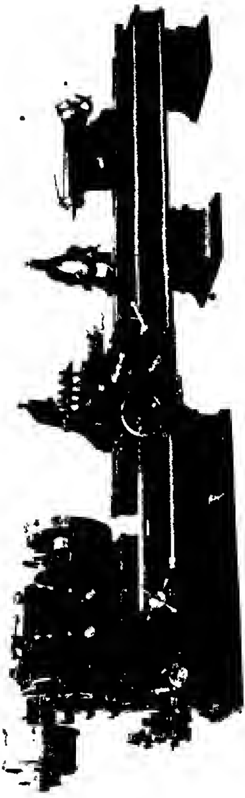


FIG. 14.—Engine lathe with all-gear head-stock.

the speed range (that is, for a large diameter of work) is working far below its normal or most effi-

cient speed and, therefore, is liable to be unduly stressed, whilst at the other end of the speed range the load on the belt is much smaller than the strength of the belt indicates. Further, the process of changing the position of the belt is always a more or less risky one, as well as a troublesome one at times.

The "all-gear" or "geared" headstock is designed to overcome these defects. This type of headstock is one in which a single belt-pulley is employed, the belt having a constant speed which is generally higher than the average belt-speed of a cone-pulley headstock. The lathe shown in Fig. 14 and manufactured by Messrs. Pollock and MacNab, of Manchester, is an example of a lathe with a single-pulley geared headstock. In this design there is no direct belt-pull on the driving spindle, and thus the alignment of the spindle is preserved. In Fig. 17 another geared-headstock lathe is shown.

To obtain the necessary gear changes any one or any combination of the following methods is available:—

(*a*) The sliding-gear method;
(*b*) The sliding-key method;
(*c*) The sliding-claw-clutch method.

A unique form of speed variator with a single-pulley drive is that which is applied to some of the lathes manufactured by Messrs. John Lang of Johnstone, Scotland. An engine lathe equipped with this form of headstock is illustrated in Fig. 15. An enlarged plan of the headstock is given in Fig. 16. The speed-variator consists of a compound belt, C, of special design with bevelled sides and of con-

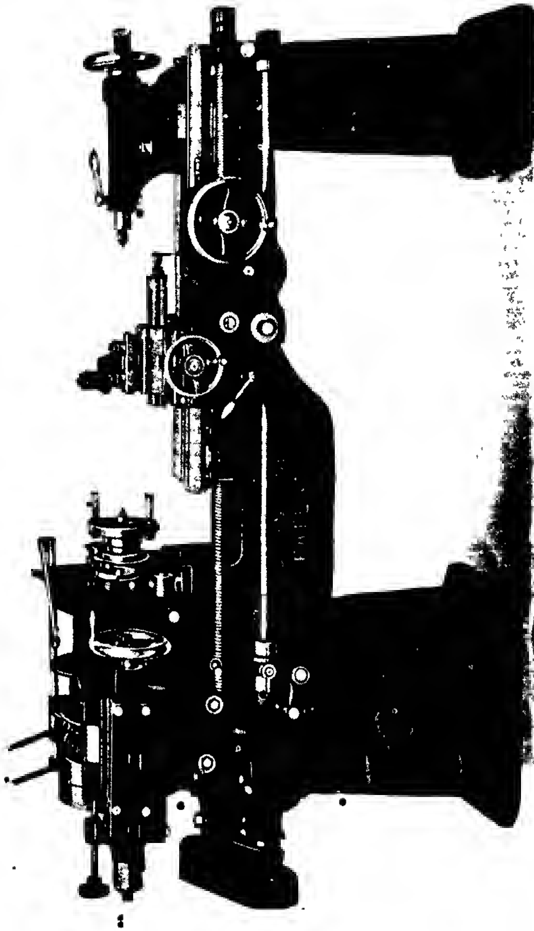


Fig. 15.—Lang lathe.

stant length, which connects two internally coned and adjustable pulleys, HF and KG. The pulley HF is mounted on the driving-pulley shaft, whilst the pulley KG is carried on a shaft which is inter-

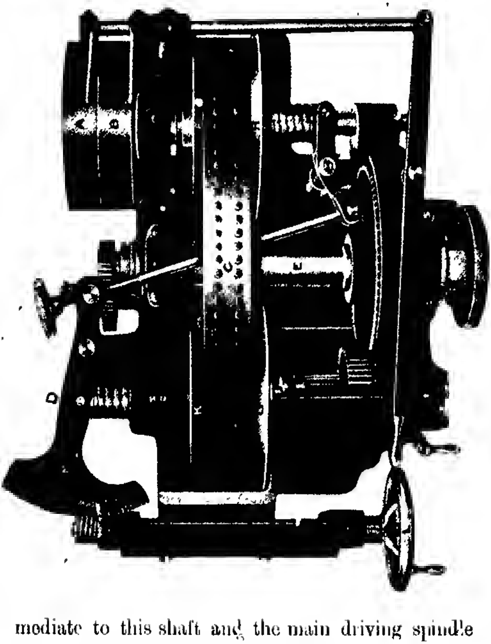


FIG. 16.—Lang speed-variator.

mediate to this shaft and the main driving spindle of the headstock. The tapered cones H and K are free to slide longitudinally on their shafts simultaneously and in the same direction (that is, either to the right or to the left). When the longitudinal movement is to the left, the belt is forced *towards the cir-*

cumference of the pulley HF and *towards the centre* of the pulley KG. This action, of course, increases the nominal diameter of the former, and reduces that of the latter and, therefore, increases the ratio of the two diameters and also the speed of the second shaft. On the other hand, a movement to the right reverses these changes, and causes a reduction in the speed of the shaft of the pulley KG. These pulley changes are obtained by means of a hand-wheel, worm, toothed quadrant, and helical springs, as shown in the figure. From the front or intermediate shaft the power and motion are transmitted through a pinion and driving wheel for the direct drive, and through treble gearing for the indirect or geared drive for the low speeds.

This motion or one somewhat similar in principle has been applied to an American lathe, but in this case the movable pulleys and belt are situated in the countershaft and not in the headstock.

The third type of headstock, namely, the motor-driven geared headstock, is one which is similar in regard to general design to the afore-mentioned "all-gear" headstock. When the motor is an alternating-current machine of the non-commutating type all the speed-changes are effected by changes of gear-dispositions. With continuous-current motors of either the shunt-wound or compound-wound variety, however, the number of possible speed-changes may be enormously increased by the use of a rheostat or variable-resistance in the field-winding circuit. To show what can be accomplished in this direction the case of a 40-B.H.P. shunt-wound motor with series inter-poles may be cited. This motor drives

an 18-inch centre lathe designed for experimental purposes, and it is equipped with two speed-rheostats placed in series with the field windings, this arrangement admitting of the obtainment of at least 1,000 different surface speeds for one diameter of work and one motor terminal voltage with a ratio of 40 to 1 between the maximum and minimum speeds. This is, of course, a very exceptional case, since in practice more than, say, 20 spindle speeds are very rarely required.

Engine-lathe driving spindles are either solid or concentrically hollow. In the case of the latter it is possible to perform machining operations on long bars and rods without having to put the work between the centres. Further they are provided with threaded noses for face-plates, chucks, and driving-plates, or flanges for driving-plates only.

The Loose Headstock or Tailstock.—In the average case, the function of this element of the lathe is two-fold: it carries the centre for the tail-end support of the work (when such is necessary), and it enables drills to be socketed in its mandrel or spindle and to be fed regularly into the work. Its design is also such that adjustments of the position of its centre can be readily made to allow for increases of length of work resulting from rises in temperature.

In all except the loose headstocks of the very simplest lathes (that is, some forms of hand-turning lathes) the principle of the screw and nut is utilized. This principle is applied in two distinctively different ways. The first involves the use of a hollow mandrel or spindle, in the inner end of which a brass,

steel, or cast-iron nut is fitted, this mandrel being prevented from rotating by means of a key or screw.

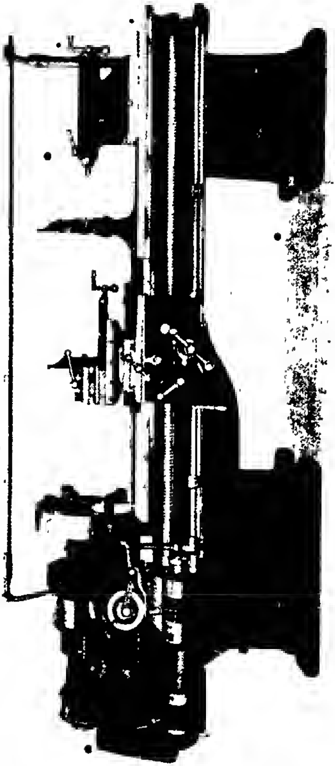


FIG. 17.—Engine lathe with geared-headstock.

The longitudinal movement of the mandrel is secured by the rotation of the screw, on the outer end of

which a handwheel or balanced handle is mounted.

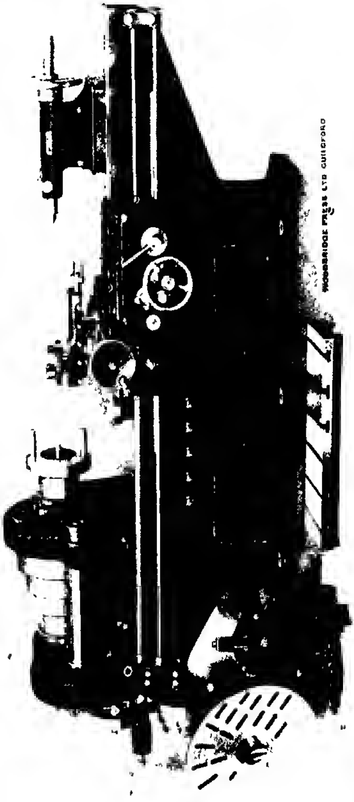


Fig. 18.—Drummond lathe.

A loose headstock embodying this principle is to be found on the lathe shown in Fig. 17. In this case

a balanced handle is employed, and the longitudinal movement of the screw is prevented by the use of a screwed cap. In the other form the handwheel acts as the nut, whilst the tail end of the mandrel is threaded and fits in the nut. Hence, the rotation is given to the nut in this case, and the longitudinal motion is received by the screw, which is, of course, prevented from rotating. This form is employed on the Lang lathe represented in Fig. 15, and on the Drummond lathe represented in Fig. 18. Its chief virtue lies in the fact that, *ceteris paribus*, a screw of a larger diameter than is possible in the case of the other form may be used. Against this must be placed the disadvantage of having a projecting screw from the tail end of the headstock when the other end of the mandrel is close in.

On large lathes it is usual to provide a gearing-down device between the handwheel or handle and the mandrel screw so as to reduce the effort required to force the centre into the work. This device consists variously of plain spur, bevel, spiral, or worm gearing, or a combination of these.

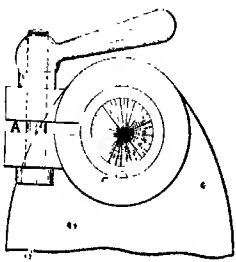
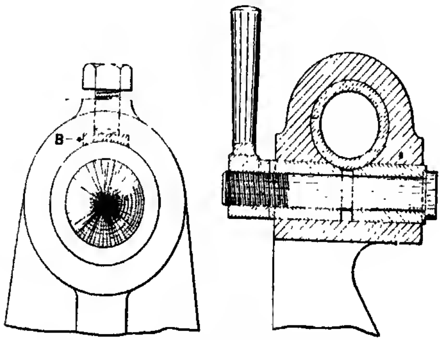


Fig. 19.—Method of gripping tailstock mandrel.

There are several methods of securing or locking the mandrel in position in the body of the headstock. The commonest for small and medium-sized lathes is indicated in Fig. 19. It is known as the "split-lug

method". A lug which is cast on the body of the headstock near the nose is split at A, and a bolt and handle nut are used to draw the two parts of the lug towards each other. This action tends to cause the body of the headstock to close over the mandrel. In many cases a strip of lead occupies the space A.

In Fig. 20 is shown the "single-screw method," which is used on small and large lathes. A single screw is screwed down on to the upper part of the mandrel, and the frictional resistance so created acts



Figs. 20 and 21.—Methods of gripping tailstock mandrel.

as the restraint to any tendency on the part of the mandrel to move. This method in its simplest form is only applied in the case of the smallest and cheapest machines, an improvement of the method being the introduction of a concave brass insert as shown in the figure at B. When such is used the surface of the mandrel is not defaced by the end of the screw. In some large lathes the end of the screw is reduced

in diameter and acts as the key which prevents the rotation of the mandrel.

A method which is known as the "twin-cylinder method" is sometimes employed. Two shaped and hollow cylinders are used (as indicated in Fig. 21), and these are disposed usually just beneath the mandrel. To lock the mandrel in position these two cylinders are drawn towards one another by means of a locking bolt and handle nut.

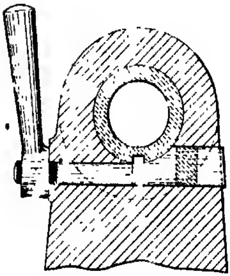


FIG. 22.—Method of gripping tailstock mandrel.

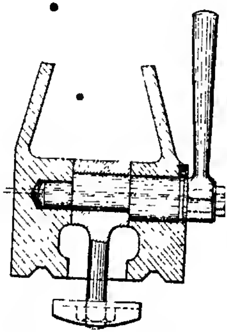


FIG. 23.—Method of holding tailstock on bed.

In Fig. 22 a method somewhat similar to the above is represented. In this case, however, the two cylinders are replaced by one shaped locking bolt. The action is practically the same notwithstanding this difference in the design of the parts of the device.

Hollow cones fitting on the mandrel have been tried and used to some little extent in America and, though the device is much costlier than any of the above, it possesses a large advantage over these inasmuch as by its use the axis of the mandrel is never

thrown out of coincidence with the axis of the lathe; this cannot be said of any of the other methods.

In regard to the holding-down of the loose-headstock on the bed of the lathe, it may be observed that there are at least four different methods in general use. In the first a clamping plate fitting under the shears of the bed and bolts passing through the plate and the base of the headstock are employed. This is the common English practice where small and medium-sized lathes are concerned. In the corresponding American method the ordinary clamping bolts are replaced by one or more eye-bolts fitted on eccentric shafts (one form of which is represented in Fig. 23). These shafts repose in the body of the headstock, and are rotated through a fraction of a revolution by means of levers. The rotation thus imparted to the shafts causes the clamping plate or plates to rise or fall, as the case may be. The necessity for the use of the spanner or wrench is thus entirely obviated. The third method (which is available for use on large lathes) involves the use of hook bolts; whilst in connexion with the fourth, tee-headed bolts fitting in tee-slots are made use of.

These methods are, of course, only available where beds of the ordinary sections are used; where beds of circular section are adapted a modified split-lug method is applicable.

Loose-headstocks are also of the non-adjustable and set-over types. In the case of the former the headstock body consists of one part, and this is capable of one movement only, viz., along the bed. In the other case the body consists of at least two parts, the upper one of which is capable of cross or

transverse movement. This latter type is found most frequently on modern lathes, since it enables long tapers to be turned expeditiously.

On one or two designs of engine lathes the loose-headstock is equipped with a pawl which can be dropped on to a rack which runs inside the bed. This prevents the backing off of the headstock and relieves the holding-down bolts when the lathe is engaged on heavy work.

The Compound Slide Rest.—This is the element that slides on the bed of the lathe, and in which the cutting tool or tools are secured. It consists of a saddle or carriage which is surmounted by two slides, one (the cross slide) running across the bed and the other (the top slide) usually at right angles to this. In the modern lathe, however, the top slide is arranged on a rotating or swivelling base and, hence, is capable of occupying any position inclined to the axis of the lathe. The tool-post or grip is secured to this top slide. In some forms of the American lathes which are rarely seen on this side of the Atlantic Ocean the top slide is dispensed with, all longitudinal traversing or sliding being obtained by moving the entire rest on the bed.

In high-grade engine lathes with full equipment, there are three automatic or self-acting slide-rest feeds, two of these being for plain longitudinal traversing (known as sliding) and plain transverse or cross-traversing (known as surfacing), and the other for threading or screw-cutting.

The two former power feeds are derived from either a back feed-shaft (as in some English types, of which the Selson lathe represented in Fig. 24 is a

good example) or a front feed-rod (as in all American

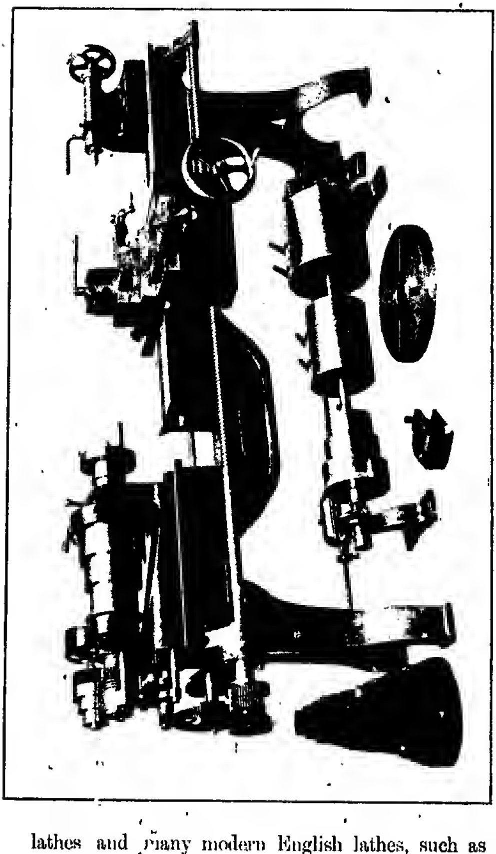


Fig. 24.—Gap lathe with back feed-shaft.

lathes and many modern English lathes, such as the one shown in Fig. 25).

The latter form passes through what is usually

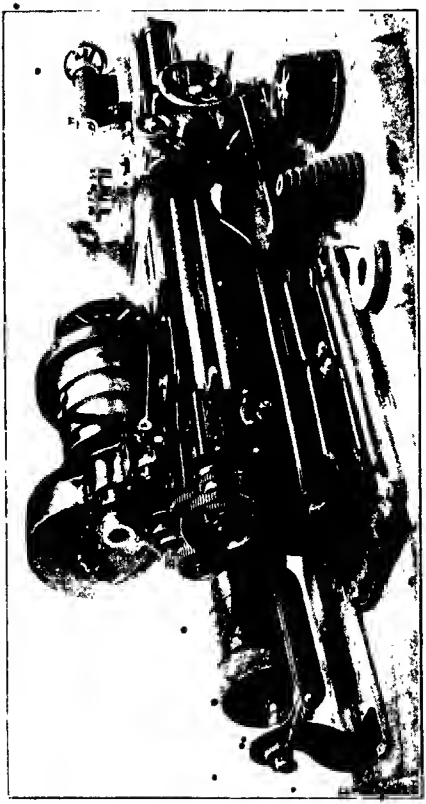


Fig. 25.—Gap lathe with front feed-rod.

termed the slide-rest feed-apron, which carries all the gear wheels between the feed-rod and the slide

feed-screws, whilst the other passes through an extension at the back of the slide-rest.

The threading or screw-cutting feed is derived from a master screw, which is known variously as the lead, leading, or guide screw. In some lathes, this screw is also used to transmit the power for the sliding and surfacing feeds, but this, if the thread of the screw is made use of, is distinctly bad practice, since it increases the rate of wear of the thread excessively, and renders the screw more or less useless for accurate screw-cutting. Where, however, the thread of the screw is not used, but a spline or long keyway in the screw, the effect is not quite so inimical to the production of good and accurate work; this notwithstanding, the separation of the lead screw and feed-rod is preferable.

The motion for sliding from the splined back-shaft, feed-rod, or lead screw is transmitted through either a worm and worm-wheel or a bevel pinion and wheel, the worm or the pinion being mounted on the feed-rod or shaft, and connected thereto by means of a key which fits in the spline in such a way that the only relative motion between the worm or pinion and the rod is an axial one. Thus the worm or pinion is allowed to slide on the rod or shaft but *must rotate with it.* Another method involves the use of a feather key in the rod or shaft and a keyway in the worm or pinion. Spiral or screw gears have also been used in place of the worm and bevel gears for the purpose of changing the axial direction of the rotating parts, but their use has not been an unqualified success.

When the bevel gear device is employed it is

possible, by using two pinions *vis-à-vis* and placing the wheel between them, to obtain a reversal of the direction of motion of the slide-rest quite simply. As a matter of fact, this device is usually designed to give the two directions of motion.

From the worm-wheel or bevel-wheel the motion and power are transmitted through spur-gear wheels and friction clutches (which are manipulated from the front of the slide-rest ordinarily) to the rack-pinion, which meshing with the rack on the underside of the front shear of the bed, causes the slide-rest to be traversed on the bed. Additional gear wheels terminate in a pinion which is mounted on the cross-slide feed-screw, and which imparts motion to the screw, and thence to the slide.

The slide-rest is moved along the bed by hand from a handle or hand-wheel, which is connected to the rack-pinion through spur gearing.

The connexion between the lead-screw and the slide-rest is, in the ordinary case, a nut split into halves, which are constrained, by means of a handle, lever, or knob on the front of the saddle apron, to move towards or away from the screw in a direction at right angles to its axis. These simultaneous translatory motions of the two halves of the clasp nut (as it is called) are derived from the rotatory movement of the controlling element in at least three ways on ordinary lathes, these being as follows:—

1. By the use of a pin in each half nut fitting into eccentric slots in the plate attached to the controlling element.

2. By the use of two pins in the control plate and an eccentric slot in each half nut.

3. By the use of either of the above arrangements, but with the substitution of straight parallel slots for the eccentric ones.

The position of the lead-screw is usually in front of the bed of the lathe. There are, however, two notable exceptions to this practice in the case of the Whitworth lathe (English) and in the case of the Seller's lathe (American). In each of these cases the screw is placed between the cheeks or girder sections of the bed; in the former, so as to apply the propulsive force as nearly underneath the resistance as possible; and, in the latter, to protect the screw as much as possible. In the Seller's lathe the clasp nut, which embraces only about one-third of the circumference of the lead-screw, is disposed in a recess just under the inside of the back shear.

The section or profile of the thread of the lead-screw is, in the majority of cases, square, the forms which provide the exceptions being the buttress and Acme forms of screw-thread.

When the lead-screw, feed-rod, or back-shaft is very long it is usually provided with at least one intermediate support, which has to be of the tumbling-bracket type, such as is represented in Fig. 26.

Feed-change Arrangements.—The power drive from the main spindle of the driving headstock is obtainable in at least four different ways. These are :—

1. By belt, with or without spur gearing;
2. By spur gearing only;
3. By chain and sprocket gearing, with spur gearing.
4. By spur and bevel or worm gearing.

The lathe illustrated in Fig. 24 is equipped with a geared belt feed drive. Two small cone-pulleys are provided as shown, one being connected by spur-gearing to the driving spindle, and the other by spur-gearing to the back-shaft. The latter pulley is placed below the back-shaft so as to admit of a comparatively long belt being used. Feed changes are effected by the movement of the belt between the two cone-pulleys from one pair of steps or diameters

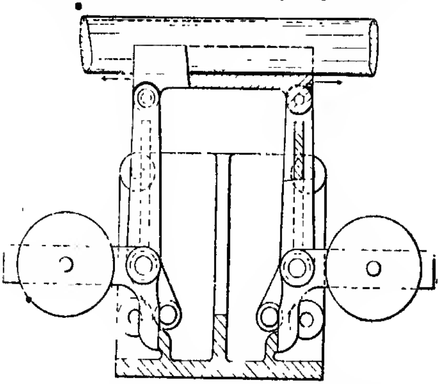


Fig. 26.—Lead-screw or feed-rod tumbling bracket.

to another pair. Since there are three pairs of steps, there are three sliding feeds available.

The second type of drive is illustrated in Fig. 25. In this case the connexion between the main spindle of the driving headstock and the feed-rod consists entirely of spur-gearing. The drive is from a small spur-gear wheel known as the first change pinion on the driving spindle, through small wheels on the cluster or reversing plate, inside the head-

stock and external gear wheels, to the change-feed gear box, and from thence to the feed-rod.

The cluster or reversing plate (which is used to reverse the direction of motion of either the feed-rod or back-shaft or lead-screw) is, in English lathes, very frequently placed outside the head-stock, whereas in nearly all American lathes in which such a simple device is used it is disposed inside the headstock, as is indicated in Fig. 25.

The principle of action of a change-feed gear box is either that of the sliding key or that of the sliding gear. Where not more than three feeds are required, either principle may be applied, but where more feeds than three are necessary, it is only the sliding-key principle which is applicable. With this device as many as six or eight feeds are obtainable.

The sliding-gear device embodies the use of three pairs of spur-gear wheels of different ratios. Three of the six wheels are mounted rigidly on one shaft (in some cases the back-shaft or feed-rod) and the other three (that is, the mating or meshing wheels) are keyed together and arranged as a whole so that they can slide on, but rotate with, the shaft which carries them. There are three positions for these wheels, so that only one pair of wheels are in mesh at any one time. The chief defect of this device (apart from the limitation of its range of usefulness) is that the gear wheels which have either the highest or the lowest ratio are situated between the other pairs, with the result that there is not a uniform progression from one extreme position of the controlling handle to the other.

In an improved design of change-feed gear box,

working on the sliding-gear principle, the middle sliding-gear wheel is arranged to connect each of the other two by means of a dog clutch to the shaft which supports them. In such a case, the feeds are progressive.

In the sliding-key device all the wheels are in mesh together. This condition is secured by arranging the two sets of wheels in the form of cones. The wheels on one shaft are keyed rigidly to it, whilst those on the other are arranged so that they can, when necessary, rotate quite freely on it. The connexion in the latter case between the shaft and any one of the wheels is obtained through the use of a key which is so designed that it can be slid along inside the shaft (which is, of course, hollow), a spring behind the key forcing it into the keyway in the wheel. Thus, the power is transmitted from the key shaft, through the key and wheel in which the key is placed to the wheel which is in mesh with this wheel, and from thence to the feed-rod or back-shaft. In such a case all the wheels on the feed-rod or back-shaft rotate at the same angular speed, but those on the other shaft have angular speeds which depend upon the respective gear ratios. Changes of feed are effected by movements of the sliding-key in the hollow shaft, these being made by means of an external lever. In some forms of this device the loose gear wheels are recessed on each side to take the key when it is desired to disconnect all the wheels from the shaft, and also to facilitate the insertion of the key in any wheel.

Modifications and combinations of the above devices have, from time to time, been made. The

Hendey-Norton change-feed gear box (in which a range of at least twelve feeds may be embodied) is a sliding-gear mechanism. It consists of a cone of spur-gear wheels mounted on the feed-rod, and in mesh with any one of these a sliding pinion may be put. An intermediate or idler gear wheel mounted in a tumbler or tumbling bracket is, however, an absolutely necessary element. Accompanying this device there is a bevel-gear reversing mechanism in place of the ordinary spur-gear device. In the Lodge and Shipley lathe the Hendey-Norton device is combined with an additional tumbling and sliding-gear device which combination augments the number of available feeds considerably. In the Springfield mechanism—a Springfield lathe is shown in Fig. 39—the change-gear wheels are arranged in a circular casing which is pivoted at its centre. The wheels, which are eight in number, are of different diameters, and any one of them may be brought opposite the end of the lead-screw or feed-rod, a telescopic extension of which is then caused to enter the hole in the boss of the wheel. The connexion is completed by the movement of a tumbling-gear wheel which is put into mesh with the active wheel on the screw or rod.

The chain and sprocket drive is not often adopted, but where it is applied feed-changes are effected by means of gearing in one of the ways described above.

In at least one make of lathe a friction-disk drive is found, the device consisting of two slightly tapered wheels which fit in an adjustable two-part conical pulley. The two parts of the pulley are pressed to-

wards one another by a spring. Feed-changes are effected by moving the adjustable cones as to alter the diameters at which the two wheels work. This action alters the ratio of their mean peripheral speeds and, therefore, their angular speeds.

It will have been observed already that the above devices may be divided into two classes, viz. those in which slip is possible, and those in which it is not possible. To the former class belong all ...ives which include a friction element, such as the belt drive and the friction-disk drive. To the latter class all the remainder belong.

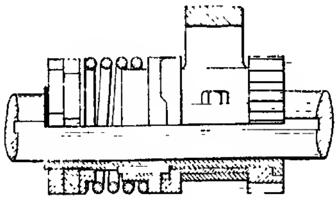


Fig. 27.—Slide-rest safety clutch.

Friction devices act as safety motions and protect the gear wheels in the various parts between the main spindle and the rack from destruction, should anything happen to the slide-rest to obstruct its motion such as, for example, excessive cross-winding and slide-locking, or an abnormal amount of resistance at the cutting edge of the tool; the protection is secured through the slipping of the belt or friction disks.

In positive and non-slip drives it is advisable to introduce a safety clutch, one form of which is indicated in Fig. 27. This consists of a sharp-angled

tooth clutch, the two parts of which are held in engagement by a strong helical spring. When the resultant axial force on the teeth of the clutch exceeds the compressive force of the spring, the clutch slips, this slip stopping the motion of the slide-rest. Adjustment of the spring-compression is possible, so that the clutch may be set to act when the resultant axial force exceeds any amount.

Where there is no safety or slip motion there is always the fear that one or more of the gear wheels will be destroyed sooner or later, especially in the case of large lathes. And even where a safety tooth-clutch is in service, if it is set up too high, there is the same fear, though to a less degree. This, of course, only applies in those cases where there is no clutch in the saddle or feed-apron.

Thread-change Arrangements.—To obtain the conditions required for the production or formation of screw threads of different pitches, it is necessary to alter the ratio of *all* the gearing between the main spindle of the driving headstock and the lead-screw. The gearing is nearly always of the spur-gear type, with the occasional use of bevel-gearing. In one or two cases, however, chain gearing is employed, but its general use is not to be commended.

There are at least three methods of effecting these changes in general use. The first method involves the use of external change-gear wheels which are mounted on a swivelling quadrant plate and so arranged that the required ratio may be made in one step or two; that is to say, either single or compound gearing may be employed. This is the original method, and still finds favour in some

quarters at the present time. On large lathes it is employed almost exclusively.

The second method involves the combination of external change-wheel gearing and internal gearing in a gear box. In this case a whole range of screw-thread pitches is covered by the mere movement of the gear-box handle, and the number of ranges possible depends upon the number of gear-ratio changes possible with the external wheels. The work of figuring out the change-gear wheels required in any case is considerably less with this second method than with the first. In fact, very often where the second method is adopted, no figuring out or calculation of any kind is required, as tables giving the screw-thread pitches under the various possible conditions are supplied with the machines.

As an indication of the possibilities of this method, attention may be directed to Table I in the Appendix, which gives the total number of screw-thread pitches obtainable by combining the Hendey-Norton change-gear box with external gear wheels having the following number of teeth: 42, 57, 63, 69, 84 and 168. This is an exceptional case, it is true, since 348 pitches are obtainable, whereas with the ordinary equipment of external gear wheels (42, 69, and 168) only 84 pitches are obtainable.

In the third method external change-wheel gearing is dispensed with entirely, and all gear changes are mechanical through the medium of handles or levers. This method involves the use of two gear boxes. Usually—as also in the case of the second method—the change-feed gear box is utilized. From 40 to 50 different pitches, ranging from $\frac{1}{2}$ inch to $\frac{1}{64}$

inch are generally obtainable when this method is applied. This method is applied in the case of the Lodge and Shipley and Springfield lathes, but in two distinctively different ways.

Methods of Holding the Tool.—There are, in general, two methods of gripping or holding the tool in the top slide of the slide-rest. These are the clamping-plate and tool-post methods. The former is essentially English, whilst the latter is essentially American.

In the clamping-plate method, which is indicated in Fig. 28, usually two plates are employed, though in some cases (especially where the service is light) only one of these is put into commission. In this figure T represents the tool, and CC the two clamping plates. These plates are normally disposed so as to be parallel to the axis of the top-slide screw, but it is possible in many cases to place them in positions at right angles to these. The plates rest on the tool, and also on a packing piece or block P which is, preferably, of exactly the same depth as the shank of the tool; the clamping plates are then horizontal. The undersides of the plates are usually

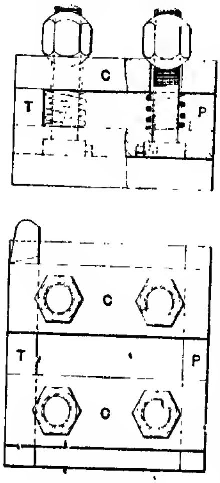


FIG. 28.—Tool-clamp.

ridged or slightly corrugated so as to present a more or less rough surface to the shank of the tool. The plates themselves are held down on the tool by nuts as shown, the nuts being screwed on studs or bolts, the shanks of which pass through the holes in the plates. The studs or bolts should be prevented from turning in the base, either by the provision of a screw, a pin key, a snug, or a square head or shank. The method illustrated in the figure is amongst the best, as it enables the bolt to be removed without any difficulty and yet prevents the bolt from being turned round should the nut stick on it. The nut-seats on the plates should be spherical preferably, so as to allow for any slight obliquity of either the plates or the bolts. Where the plates are very heavy (as they are on large lathes) helical springs are used under the plates to prevent them from dropping on to the base on the removal of the tool. This provision reduces the amount of labour which is involved in replacing the tool.

In some designs the clamping plates are placed over tee-headed bolts the heads of which fit in tee-slots which are arranged across the top slide. This method is not, however, as good as the above mentioned.

The tool-post method is indicated in Fig. 29. The post which has a tee shaped base fits in a tee-slot in the top slide of the slide-rest. The tool is placed in a vertical elongated slot, and is secured in position by *one* screw, as shown, the tightening-down of the tool being accompanied by a nipping-up of the tool-post base in the tee-slot. The tool has, however, to rest on either the top of the slide or on some form of

packing which is not rigidly connected to the tool-post.

The chief quality which is claimed for the tool-post is its extensive adjustability. Usually, it is possible to move the tool-post from one side of the top-slide to the other, and also to swing the tool through any angle. Further, height or vertical adjustments are invariably easily and expeditiously made.

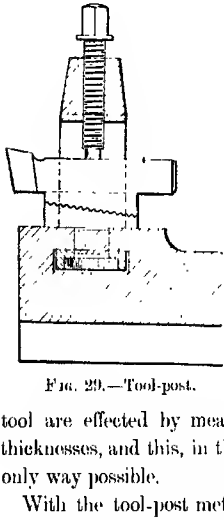


FIG. 29.—Tool-post.

In connexion with the clamping-plate method adjustments of the height of the cutting edge of the tool are effected by means of packing of various thicknesses, and this, in the majority of cases, is the only way possible.

With the tool-post method, however, this is only one of the many ways available. In Fig. 29 the tool-post is shown provided with two wedge-shaped strips which fit in the vertical slot in the body of the tool-post immediately beneath the tool. The contact surfaces of the two strips are grooved or serrated, and height-adjustments are made by merely moving one strip on the other and thus altering the positions of the serrations on the two strips with respect to each other. In Fig. 30 some other methods which are in more or less common use are illustrated. The methods shown at A and B are somewhat similar. In each case a ring or thick

washer, which surrounds the body of the post, is used, the first being concave, and the second convex. On each washer rests a shoe, which is curved in the opposite way to the washer, so that in the first case it can move *in* the washer about the centre of curvature, and in the second case *on* the washer above the centre of curvature. In each of these two cases it will be observed that an adjustment of height is obtained by tilting the tool, an operation which alters its working angles. A stepped washer is shown at C. Four pairs of steps are usually provided, the elements of each pair being placed diametrically opposite one another.

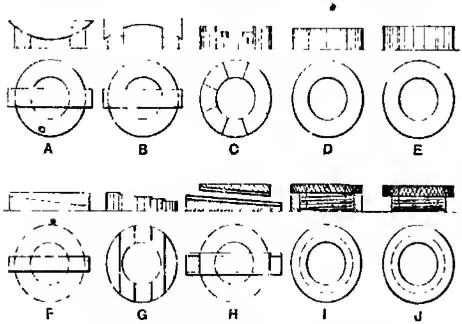


FIG. 30.—Tool-post washers and wedges.

Delicate height-adjustments are not obtainable by this means. At D tapered washers are shown. Height-adjustments are secured by sliding the upper washer up or down the lower one. The contact surfaces are sometimes left smooth and sometimes serrated; when they are serrated the risk of the upper washer slipping down the lower one under the influence of the pressure exerted by the holding-

down screw on the tool is reduced to a negligible amount. Rings or washers of different thicknesses are sometimes employed, as shown at E. In this case, however, height-adjustments cannot be made very expeditiously. The method shown at F is similar to that shown in Fig. 29, though in this case the contact surfaces are quite smooth. At G another form of stepped washer is shown. The steps are not used, however, to support the tool but to provide a slightly inclined seat for the tool, the height of the cutting edge of the tool being adjusted by sliding the tool up or down on the edges of the steps. The principle of the method shown at H is precisely the same as this, though in this case two grooved tapered packing pieces are used, this arrangement providing for normal contact between the end of the holding-down screw and the upper piece. The height of the cutting edge of the tool is altered, when either of the devices shown at I and J is adopted, by moving the tool in a direction at right angles to its length. The method shown at I involves the use of a round nut and short flanged screw. In the other case, also, these two elements are used, but they are reversed, the tool resting on the screw in the first case, and on the nut in the second. The screw-thread should be of square or buttress section.

An unusual form of tool post is indicated in Fig. 31. The upper face of the base is curved and fits against a correspondingly curved surface of a washer in the tee-slot of the top-slide. The tool rests on a washer or ring which surrounds the tool-post body, the underside of this washer or ring being internally curved and fitting against the externally curved sur-

face of another washer or ring. The four curved surfaces have a common centre, so that the tool-post as a whole can be swung about this centre through a small angle out of the vertical. Height-adjustments are made partly by swinging the tool-post over, and partly by adjusting the position of the tool in the post.

In Fig. 32 is represented the Homan ring tool-post.

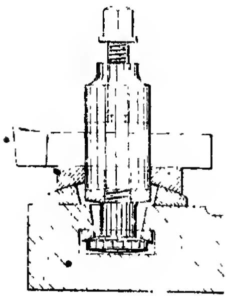


FIG. 31.—Tool-post.

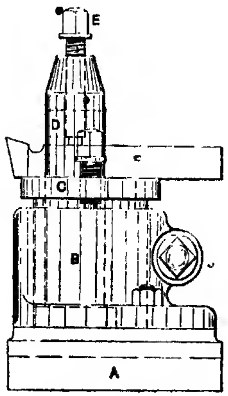


FIG. 32.—Homan tool-post.

This is a tool-post of an almost universal character. It consists of a flanged, slotted ring B, an eccentric bush C, and the tool-post proper D. The ring B is mounted on the top slide A and secured thereto by means of a couple of bolts and nuts. The heads of the bolts fit in an annular tee-slot, and in the neck of the slot a tongue or ward on the underside of the flange of B fits. Hence, B is capable of being rotated through a complete revolu-

tion, if necessary. The flanged sleeve C fits in the ring B, and is held therein by a screw G, which is placed in the two parts of a split lug on the side of B. The position of the flange of C is altered by screwing the elevating screw F in or out of the flange. The end of this screw should be reduced in diameter, as shown, and preferably hardened. The tool rests on the flange of C and in the slot in the post D. It is held down by the screw E, which also draws the tee'd end of the post into a recess in the underside of C. The vertical axes of the post, D, the bush, C, and the ring, B, are ordinarily non-coincident, so that three different movements are imparted to the tool by turning B on the top slide, by turning C in B, and by moving D in C. By turning C through 180° it is possible to cause the axes of B and D to coincide. Height-adjustments are made by manipulating the screw F when the lug-screw G is slack.

A design of tool grip which is intermediate to both the English and American designs is represented in Fig. 33. In one form or another it is generally found on lathes of German design and occasionally on English and American lathes. It consists of a heavy swivelling clamping head with a vertical axis, a vertical stud, which is secured in the top slide, passing through the centre of the boss of the head and terminating in a nut and washer which rest on the upper surface of the head. A horizontal piece projects from the boss, and in this two holding-down screws are placed, these screws pressing down on the shank of the tool. Adjustments in a horizontal direction are effected by swinging the head round

about the axis of the central stud; vertical or height-adjustments are effected by means of packing strips of various thicknesses. It will be noticed that this type of tool grip differs from the ordinary English type inasmuch as the hold is a screw hold and not a plate hold, and from the ordinary American type since two screws are employed instead of only one.

A slightly different form is indicated in Fig 34.

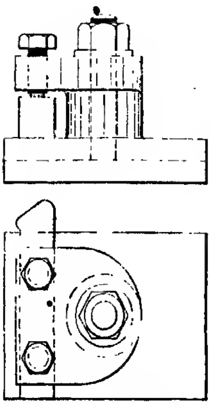


FIG. 33.—Tool-clamp.

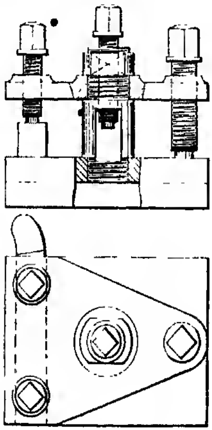


FIG. 34. Duplex tool-grip.

This is a duplex form of grip, since it admits of a tool being secured in two different ways. It consists of a clamping plate, which is mounted on a central pillar in such a way that the plate is capable of being swung through a complete revolution and held in any position by a nut which is screwed on the pillar. Two screws are employed to hold the tool, and another is used on the opposite side of the pillar to

take the place of packing or blocks under the plate to keep it horizontal. The pillar is provided with a vertical slot, as shown, in which a tool may be placed, a screw in the centre of the pillar acting as the holding-down screw. The two grips are quite independent.

Another form in which two holding-down screws are used is the one which is frequently found on lathes designed for machining crank pins and webs. This form has to be comparatively narrow so that it can be fed in between the crank webs without introducing any obstruction. The top of the slide, which is usually considerably elevated above the slide feed-screw, is, therefore, provided with two dovetailed slots in which fit the ends of two inverted U straps. Each strap carries one of the holding-down screws, and it is so designed that it can be moved along the slots to allow for variations in the lengths of the tools.

Some Engine-lathe Design Data.—The following data represent average engine-lathe practice, and do not cover abnormal or special cases, such as, for example, lathes with extra long beds. The height of the centres above the shears of the bed, measured in inches, is taken as the basis, and all the other dimensions are given in terms of this dimension, which is represented by H in the following formulæ. These formulæ give generally the limits of the respective dimensions. In addition the following letters are used and have the given meanings: D = diameter, in inches; n = number of threads per inch.

Length of bed = $(H \pm 1)$ feet.

Breadth of bed = $1{\cdot}5 \times (H \pm 1)$ inches.

Depth of bed = $(H \pm 1)$ inches.

Greatest distance between the centres = 6 × (H ± 1) inches.

Greatest diameter or swing over the saddle = 1·25 (H ± 1) inches.

Total weight of lathe = (H ± 4) × 600 lb.

Largest cone-pulley diameter = 1·25 × (H ± 2) inches.

Width of cone-pulley steps = 0·25 × (H ± 1) inches.

Ratio of widths of back gears = 0·60 to 0·90 (average = 0·80).

Ratio of pitches of back gears = 0·60 to 0·875 (average = 0·75).

Taper of journal-neck cones = 1 : 6 to 1 : 3.

Included angle of journal-neck cones = 10° to 20°.

Diameter of nose of spindle = 0·3 × (H ± 1) inches.

Threads per inch on spindle-nose = 0·5 (20 − H).

Mandrel screw of loose headstock :—

D = 0·15 (H ± 1) *for internal mandrel screw.*

D = 0·25 (H ± 1) *for external mandrel screw.*

$$n = \frac{40}{(H \pm \ )}.$$

Diameter of mandrel of loose headstock = 0·25 (H ± 1) inches.

Diameter of back-shaft or feed-rod = 0·13 + (H ± 2) inches.

Lead screw : D = 0·2 × (H ± 1).

n = 0·5 (22 − H).

Driving-headstock spindle-speeds.—The maximum and minimum spindle speeds are selected so that the surface speeds on the largest and smallest diameters of work which can be dealt with are reasonable, though the definitions of a reasonable speed vary considerably. The maximum speed, in revs. per

min., $= 500 - (10 \text{ to } 15)$ H. The minimum speed $= 30 - (1{\cdot}0 \text{ to } 1{\cdot}5)$ H.

Countershaft speed.—This varies from 80 to 250 r.p.m. for single speeds, the higher values being adopted in the case of the smaller machines. When there are 2 countershaft speeds, the ratio between the two lies between 2 and 3, and the lower speed lies between 100 and 150 r.p.m. This speed ratio is an intrinsic element in the design of the speed arrangements of the lathe. The product of the height of the centres, in inches, and the countershaft speed, in r.p.m., varies from 840 to 1400.

Horse-power required.—This is approximately equal to $0{\cdot}3 \times (H \pm 1)$ for carbon-steel lathes; to $1{\cdot}0 \times (H \pm 1)$ for intermediate or compromise lathes; and to $2{\cdot}0 \times (H \pm 1)$ for high-speed-steel lathes. These formulæ represent the gross horse-powers required in ordinary practice, and will serve to determine the maximum gross horse-power likely to be required in any average case.

Treadle or Foot Lathes.—Where mechanical or electrical power is not available for the driving of lathes, the treadle or foot motion has to be used. The principle of action of this motion is that of the crank and connecting-rod, the oscillatory motion of the treadle or pedal being converted into the rotatory motion of the crank and driving wheel or wheels.

The treadle may consist of a long foot-board (as in the case of the Drummond lathe, Fig. 35) or a narrow pedal, pivoted about the axis of a shaft parallel to the lathe and situated at the base and back of the lathe standards. The former arrange-

ment of the two is the better, as its use does not entail stretching and straining on the part of the operator.

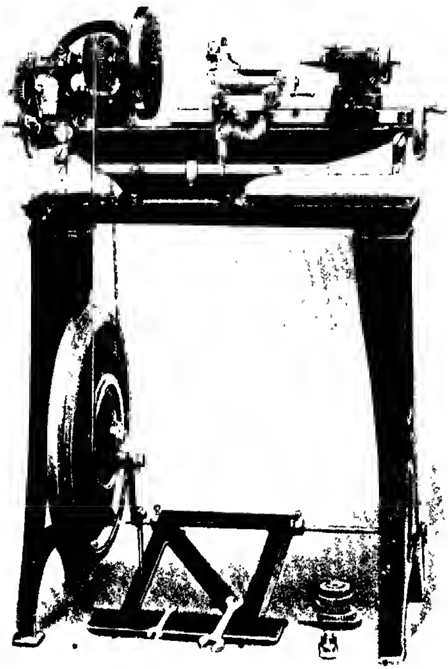


FIG. 35.--Foot or treadle lathe.

The crank-shaft may have one bearing in the frame of the lathe (as in Fig. 35) or two (as in Figs.

36 and 37). When only one bearing is used, the crank is of the overhung type (either inside or outside), whilst, in the other case, either eccentrics (Fig. 36) or bent cranks (Fig. 37) are available. When the shaft extends from end to end of the lathe, and a treadle board is used, two cranks or eccentrics are employed.

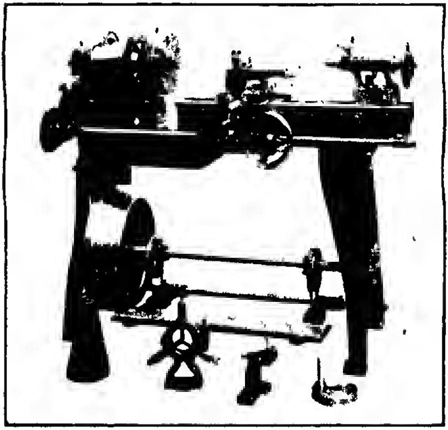


FIG. 36.—Foot or treadle lathe.

Three forms of connexion between the treadle or pedal and the crank or eccentric are in common use. These are: (*a*) the rigid metal rod (Fig. 35); (*b*) the flexible endless chain (Figs. 36 and 37); and (*c*) the flexible endless belt. By means of any one of these the two directions of rotation are obtainable.

To connect the crank or eccentric shaft to the main spindle of the driving headstock, a belt is

used, the section of this being either circular (Figs. 35 and 37) or rectangular (Fig. 36). The former is only suitable for very light lathes.

Lathe with Two Lead-screws.—This is shown in Fig. 38. One of the screws is reserved solely for screw-thread cutting, whilst the other is used in

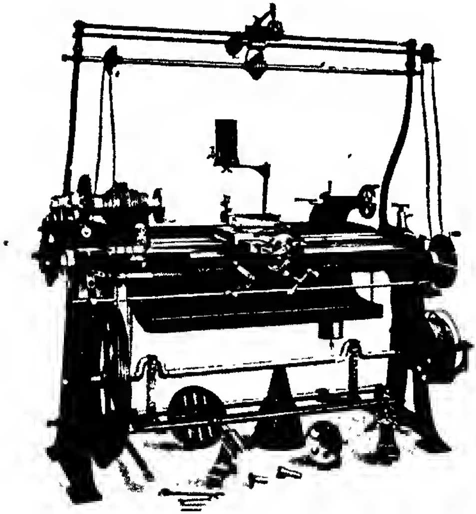


FIG. 37.—Foot or treadle lathe.

place of a splined feed-rod or back-shaft for sliding. Each screw receives its motion from the main spindle of the driving headstock through change-wheel gearing and a short horizontal shaft. Each screw is connected to the latter by means of simple spur gearing, which is so arranged that either screw

may be disconnected, the process of disconnecting involving only the sliding of a spur-gear pinion.

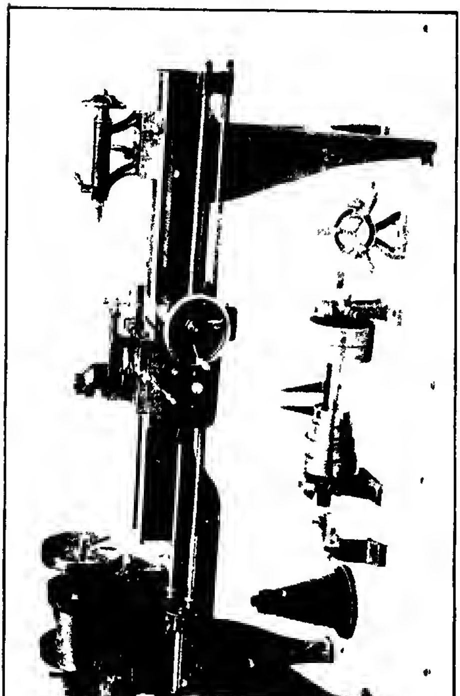


Fig. 38.—Engine lathe with two lead screws.

In special cases the two screws could be used for

screw-thread cutting, the value of the lathe being

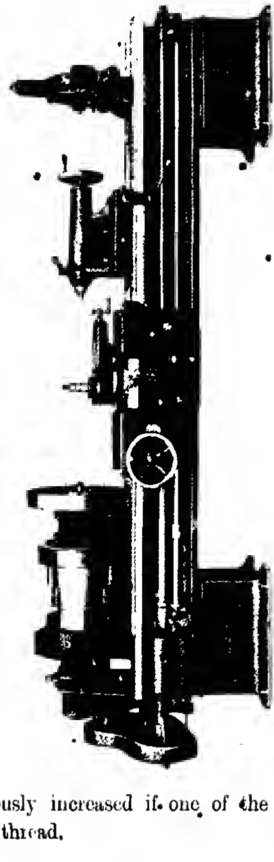


FIG. 39.—Springfield engine lathe.

enormously increased if one of the screws had a metric thread.

An American Lathe.—Such a lathe is represented in Fig. 39. It is a Springfield lathe and possesses all the features which are characteristic of American engine lathes. The size of an American lathe is usually defined by the magnitude of the "swing," whilst that of an English lathe is defined by the value of the "height of the centres". The latter is, usually, very definite, the actual amount very rarely differing by more than ¼ inch from the nominal amount. With the swing, however, it is different.

By the term "swing" is meant the *nominal maximum diameter* of work that can be swung or rotated *over the shears* of the bed. The actual maximum diameter of work that can be swung over the shears is, however, invariably greater than this, the variation ranging from ½ inch to 2 inches. On the other hand, the maximum diameter of work that can be swung over the saddle of the slide-rest is considerably less than the nominal swing.

As an approximate rule the *swing* of a lathe may be taken as twice the height of the centres above the shears of the bed.

CHAPTER VI.

TURRET LATHES.

Differences between Engine-lathe and Turret-lathe Methods.—Machine-tool practice generally may be said to embrace two systems which are essentially different. The first—and the older of the two—covers the special production and machining of parts in small quantities (frequently in units); the other covers the more or less rapid production and machining of parts in large quantities (sometimes in thousands) and is known as the repetitive manufacturing system. The methods which are embraced by one system are distinctively different from those which are included in the other.

The initial difference between the two systems is to be found in the general arrangement of the tools which are presented to the work and in the relation of these tools to one another. In the first system each tool is secured in its holder and caused to perform its work, after which it is removed to make place for the tool which is required for the performance of the succeeding operation, and so on. This is ordinary engine-lathe practice, in which one tool is held in the slide-rest at a time, and removed when it has done its work. In some cases several tools in one or more slide-rests are used simultaneously,

but each is suitable for one operation only and has to be removed before the next operation can be performed on the work. Where the work is of large dimensions, or of intricate design, this is the only method which is available.

In the second system the tools which are required for the various operations on a piece of work are arranged with respect to each other in such a manner that each tool, in turn, is presented to the work. In this case, therefore, a change of operation does not involve an *exchange* but only a *change* of tools, this being effected automatically or, at least, mechanically. This is the fundamental principle of turret-lathe practice, which covers the production of small parts—there is a limit as to size—on which several somewhat similar or, at least, closely related operations have to be performed.

Where the number of parts is not very large, and where the number of operations is also small, it may not always pay to use a turret lathe, but in all other cases there is no comparison between the rates of production of the two methods, since, in the case of the turret-lathe method, there is practically no tool-setting required after the initial setting-up.

Principle of Turret-lathe.—The tools of a turret-lathe are held in a revolving turret-head, which is so designed that it is locked in position during the time that each tool is at work. One form of turret-head is represented in Fig. 40. In this head six different tools can be held, six being the usual number. The head is mounted on a slide which works in guides arranged in the upper part of a hollow saddle which rests on the lathe bed and

which can be clamped down or gibbed in any position thereon. The slide is moved to-and-fro by means of a handle, lever, or hand-wheel. When a handle is used it is usually of the four-armed capstan type (the lathe then being known as a capstan lathe), and it is mounted on a spindle that carries at its inner end a pinion, which is in mesh with a rack on the underside of the slide. Inside the saddle and underneath the slide the ratchet indexing and lock-

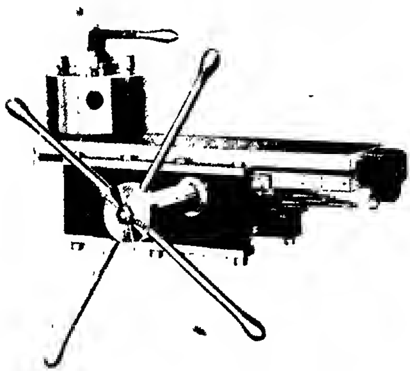
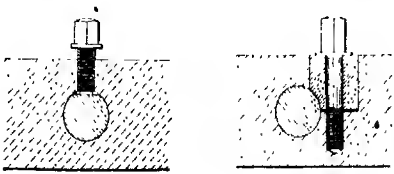


Fig. 40.—Turret slide and head.

ing mechanisms are provided. Usually, the indexing and locking actions are performed automatically at the end of the return stroke of the slide. In some cases, however, the locking has to be performed externally by the operator of the machine.

In the ordinary form of turret, which is either circular or hexagonal in plan, the tools are carried in holders which are provided with circular shanks, these shanks being fitted in holes whose axes are

normal to the axis of the turret and coincident with the lathe-spindle axis when in the working position. The two commonest methods of securing the shanks of the holders in position are indicated in Figs. 41 and 42. The first method (Fig. 41) which is the simpler of the two, is known as the "set-screw method," since a plain set-screw or tap-bolt is used, the lower end of the screw pressing on the shank, which should, preferably, be provided with a flat, as shown. The end of the screw is usually reduced in diameter below that of the bottom of the thread, and also either hardened or case-hardened. The second



Figs. 41 and 42.—Methods of securing tool-holders in turret.

method involves the use of a binding bush, which is pressed downwards on the shank by means of a set-screw which is screwed into the turret head. The shank in this case is not provided with a flat since the bushing is curved to suit the shank and merely pressed hard against it. This method does not produce a grip which is as strong as that which is obtained by means of the other method, but it has the advantage of not damaging or marking the surface of the shank. A variation of the second method involves the use of two bushings, one above (as shown in the figure) and one below the shank. In this case the lower is drawn up against the shank

at the same time as the other one is pressed down, the set-screw being screwed into the lower one and arranged to "clear" the upper one. A stronger grip is secured in this way.

Plain Turret or Capstan Lathe. One form of this by Bardons and Oliver is represented in Fig. 43. This machine is capable of being provided with eight

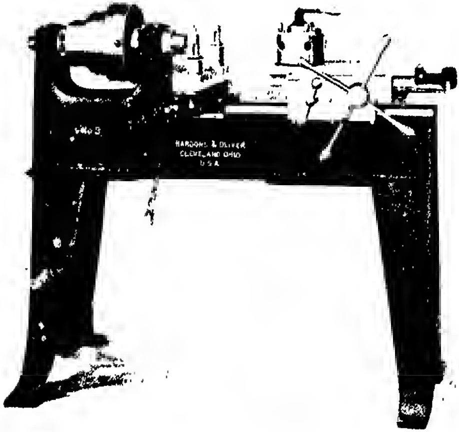


FIG. 43.—Plain capstan lathe.

tools altogether, six in the turret head, and two in tool posts which surmount what is called the cutting-off side.

Turret-lathe headstocks are provided with either the cone-pulley or the constant-speed-pulley drive. In the former case, the number of cone-steps is generally three, the number of speed-changes possible being increased to six in some lathes by the use of

double back-gearing. More than six spindle speeds are very rarely incorporated in the design of turret-lathes. The headstock spindle is invariably hollow, since the turret lathe is one designed for bar work, the bar being carried in the spindle and fed along through the chuck gradually.

The turret slide is usually arranged so that its position can be adjusted only in a direction coincident with that of the lathe-spindle axis. In some forms, however, a cross or set-over adjustment is possible, this rendering the use of tools possessing a large amount of overhang—the enemy of rapid and accurate production—quite unnecessary. A turret slide equipped with this movement is provided on the turret lathe shown in Fig. 43. A variation of this is to incorporate the cross-sliding movement in the headstock, but this is possible in the case of headstocks of special design only. It cannot be applied to the ordinary cone-pulley headstock.

In regard to the arrangement of the stops for the various tools in the turret, there are two distinctively different methods in vogue. The first, and the older of the two, is to provide a single screw-stop at the tail end of the slide, and to arrange the tools in their respective holders so that this stop acts for all the tools. The disadvantage of using this method is to be found in the fact that, if the adjustment of the stop is slightly altered for any one of the tools, the setting of each of the other tools is affected thereby. It is, however, much simpler than the second method, which involves the use of individual screw-stops for all the tools, that is, usually six. This method, naturally, allows great flexibility in regard to the setting of each

tool, and any adjustment of the stop for one tool does not affect the setting of any other tool

The cross cut-off slide may be either rack or screw actuated. The use of the rack enables the movements to be made much more quickly than they can be made by means of a screw, but the control of the slide is much more positive in the latter case. The rack and pinion method is represented in Fig 43, and the screw and nut method in Fig. 44. The tools are carried in slotted posts. The bases of the posts are placed in tee-slots which are formed in the slide, and the tools themselves rest on stout screws and nuts of a design similar to the one which has been already described and illustrated in Fig. 30 (I).

The turret lathe shown in Fig. 44 is by Messrs. C. Taylor, Ltd., of Birmingham. It is provided with a weight feed for feeding the bar stock along after a piece has been cut off and the chuck (which is of the spring collet type) has been opened. The opening of the chuck is effected by means of the projecting horizontal handle or lever just beyond the headstock. The tool posts on the cutting-off slide are open-side posts, and not posts of the American pattern. This lathe is a capstan turret lathe, as is also the one shown in Fig. 43.

The Hartness Flat-turret Lathe.—This is a machine which is made by the Jones & Lamson Machine Co., and on which both bar and chuck work can be done. The chief features which distinguish it from other turret lathes are two in number: first, the turret is in the form of a flat plate on which the tool-holders are mounted; and, second, the headstock is provided with a cross-slide. Another point of

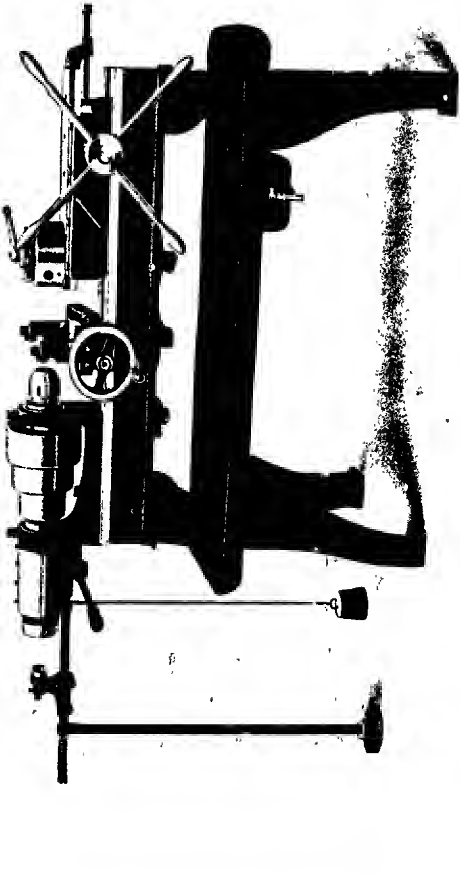


FIG. 44.—Capstan turret lathe.

difference between this lathe and the ordinary turret lathe which is worthy of notice is that the headstock is of the "all-gear" type.

Provision is made on the turret plate for six toolholders, and altogether twelve stops are available, two for each position of the turret, one forward and one reverse. As many as eleven or twelve tools can be arranged on the turret for use in rapid and regular succession. The turret slide is controlled by means of a capstan handle.

The cross-slide of the headstock is arranged with nine or ten stops, so that the headstock can be located in any one of nine or ten positions. That is, the work can be moved into any one of these positions for the purpose of working on a definite circumference of it. The transverse movement of the headstock is effected by means of a capstan handle.

The feed for bar work is obtained by means of a roller mechanism. This consists essentially of two rollers, which bear on the bar (irrespective of its section). These rollers are each connected to the lever by which the chuck is opened, there being three pairs of worm gears between the lever and each roller. The feed is, of course, a friction feed.

The ordinary form of this machine with only one driving spindle is illustrated in Fig. 45. In this figure the machine is shown with a chucking outfit for castings and forgings.

A recent development of this machine with two parallel driving spindles is represented in Fig. 46. This probably represents the highest type of turret lathe yet invented.

In Fig. 47 are shown the two spindles of such a

machine. The driving gear wheel on each spindle

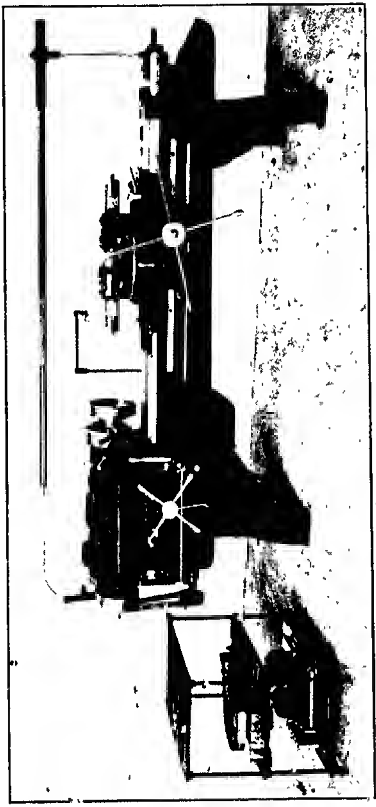


Fig. 45.—Hartness flat-turret lathe.

is solid with the spindle, and the chucks are stiffly supported close up to the main journals.

The Ring-turret Lathe.—The turret of this

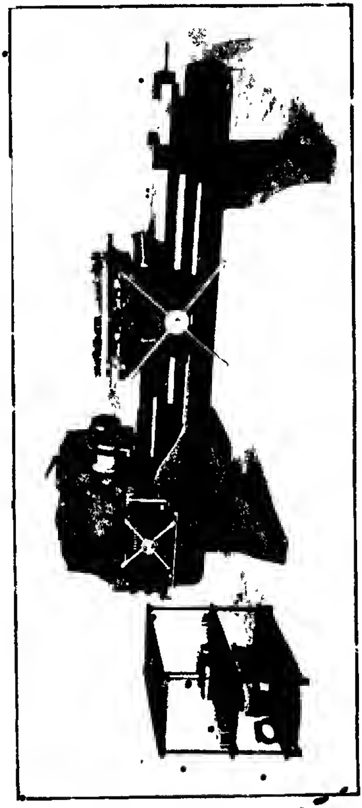


Fig. 46.—Hartness two-spindle flat-turret lathe.

lathe is arranged on a ring or circular plate which has a horizontal axis of rotation and which usually

completely encircles the bed of the lathe. The tool-

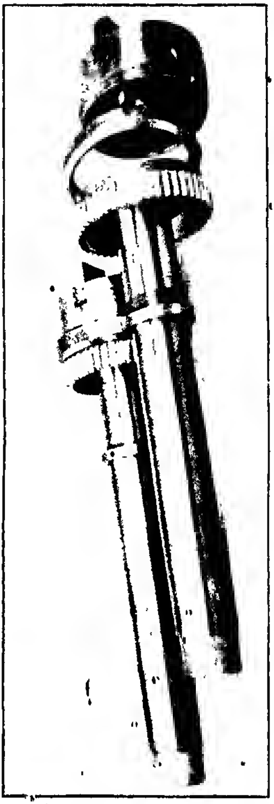


FIG. 47.—Driving spindles of flat-turret lathe.

holders (of which there may be as many as eight) are secured to this plate.

The Turret Chucking Lathe.—One form of this

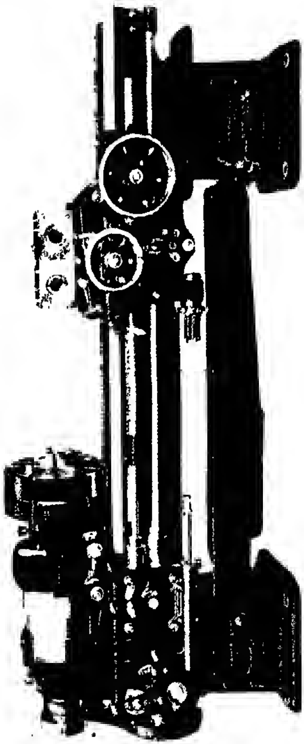


Fig. 48.—Turret chucking lathe.

is indicated in Fig. 48, which represents a lathe manufactured by Messrs. H. W. Ward and Co.,

Ltd., of Birmingham. This machine is suitable for all kinds of chucking and bar work, but it is especially well adapted for the former. The headstock is fitted with a three-step cone pulley and two sets of double back-gearing, so that, with 2 countershaft speeds available, 18 spindle speeds are possible, and these range from 7 to 360 revolutions per minute.

The turret, which is of the hexagonal type, is mounted on a sliding saddle which is somewhat, though not quite, similar to the compound slide-rest of an ordinary engine lathe. The saddle is equipped with automatic sliding, surfacing, and screw-cutting motions, which are driven from the tail of the headstock spindle (which is hollow) through external gearing and a change-gear box under the headstock. These gears give 8 changes of feed to the sliding and surfacing motions and 4 changes to the screw-cutting motion. These feeds are reversible, the reversion being effected by means of a lever on the gear box. Six adjustable automatic stops are provided for each motion, and these are so arranged that by their use six different diameters and six different lengths may be turned. Feed changes are made through the medium of one lever on the gear box when the machine is running, and this is interlocked so that it is impossible to get two feeds in at any one time. The saddle can be gibbed to the bed of the lathe when it is desired to use only the surfacing feed.

Screw-thread cutting or chasing is done by means of a leader or leading screw which is removable. Such an element is not incorporated in the design of plain turret lathes, though on some of the turret

lathes built for special work screw-threads are formed by means of dies and taps, the motions of which are controlled by leaders. In this case the leader controls the motion of the threading tool or chaser in precisely the same manner as the leading screw of an engine lathe controls the motion of a screw-cutting tool. In connexion with this machine leaders of different thread pitches are available, and with each leader four threads of different pitches may be cut, and these may be either right or left hand. The changes in the gear box are in the ratios of 1, 2, 3, and 4 to 1, so that, with a leader of a ¼-inch pitch in use, screw-threads of 4, 8, 12, and 16 per inch can be cut.

A unique feature of this lathe is the connexion between the stopping of the screw-cutting motion and the withdrawal of the tool from the cut. This connexion is such that both these actions are controlled by the same lever and, therefore, occur simultaneously.

The Hexagon Turret Lathe.—This is a development of the plain turret lathe, and is generally a much larger and heavier machine than the latter. The example dealt with here is manufactured by Messrs. Pollock & MacNab, of Manchester, and illustrated in Fig. 49. The headstock of this particular machine is of the all-gear type, the drive being from an electric motor directly through spur pinion and wheel. The number of spindle speeds available is 16, and these are derived from one motor speed. The spindle is hollow, and the chuck for gripping the bars, etc., is automatic and actuated whilst the machine is in motion. The end thrust, due to the

cutting action of the tools; which is transmitted

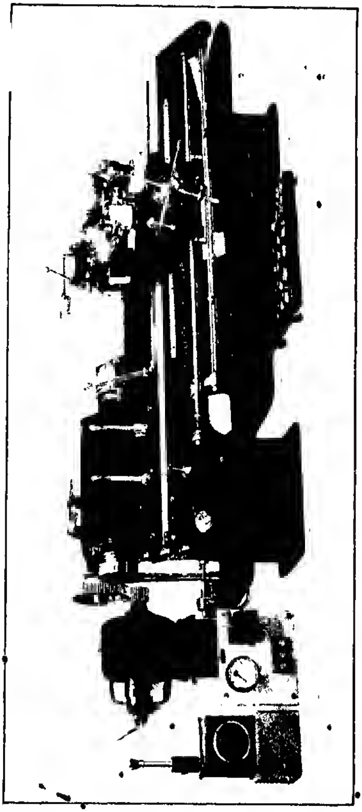


FIG. 49.—Hexagon turret lathe.

through the spindle and chuck, is taken up radial ball bearing.

The turret is mounted on a saddle which slides on the bed of the lathe, and whose motion is controlled by a capstan handle, as shown in the figure. The saddle is arranged so that a power feed may be applied to it, this feed being obtained through a feed-gear box and splined feed rod from the driving spindle of the headstock. The feed rod passes through the apron of the carriage, the apron drive from the rod being a worm-gear drive fitted with a ball thrust bearing. The turret is rotated by hand, and not automatically as in the majority of turret machines. Thus it is a simple matter indeed to rotate the turret backwards for any purpose whatever, an action which is impossible on the mechanically controlled turret. Each position of the turret is located exactly by means of a spring plunger, which sliding in a hardened steel sleeve, is ground into hardened and accurately ground steel thimbles or bushes.

A leading screw is provided for threading purposes, and is used either independently of, or in conjunction with, the die-head.

Twelve dead stops are provided on a hexagonal rod, which is situated below the feed rod and leading screw. This rod is connected to the turret and moves through one-sixth of a revolution for each movement of the turret. There are thus two stops for each face of the turret, one of these being forward of the turret carriage, and the other behind. In connexion with each of these stops there is an automatic trip, so that, if the power feed is in action, this is automatically thrown out when the stop is reached.

The Surfacing and Boring Turret Lathe.—This

is a machine which is not very different from either of the other two machines which have just been dealt with. It is designed, however, chiefly for chuck work by which is meant work which involves the use of an independent-jaw chuck, such as the machining of rough castings and forgings. An example of such a machine is given in Fig. 50. This is a Lang lathe, the headstock of which is fitted with their variable-speed mechanism.

The turret is mounted on a compound slide-rest, to which power feeds for both the surfacing and longitudinal movements are given. These power feeds are derived from a front feed rod in the usual manner.

A feature of this lathe is the provision of an automatic speed-changing device, by means of which the speed of the spindle and, therefore, of the work, is automatically increased or decreased as the diameter of the work which is being worked on is reduced or increased. The mechanism consists of a chain, which is driven from a horizontal shaft connected to the cross-slide feed screw, and which drives the handwheel for altering the effective diameters of the two belt pulleys in the headstock. The ratio between these two diameters is thus gradually changed as the tool is moved towards or away from the centre of the work, this resulting in a change in the angular speed of the spindle and work. The object of this application is to maintain constancy of cutting speed, a condition which could not be realized if the headstock were of the cone-pulley type.

The Combination Turret Lathe.—This is a turret lathe in which a slide-rest, which carries a simple tool holder (either of the plain or turret type), is com-

bined with the turret saddle or carriage which constitutes it a turret lathe. It is, in fact a type of

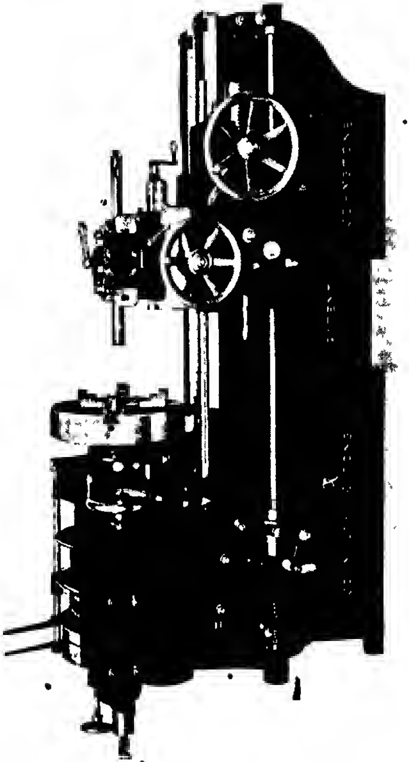


Fig. 50.—Boring and surfacing turret lathe.

engine lathe, the addition of the turret saddle differentiating it from ordinary engine-lathe types.

One form of this machine is represented in Fig. 51.

The turret saddle is actuated by means of a capstan

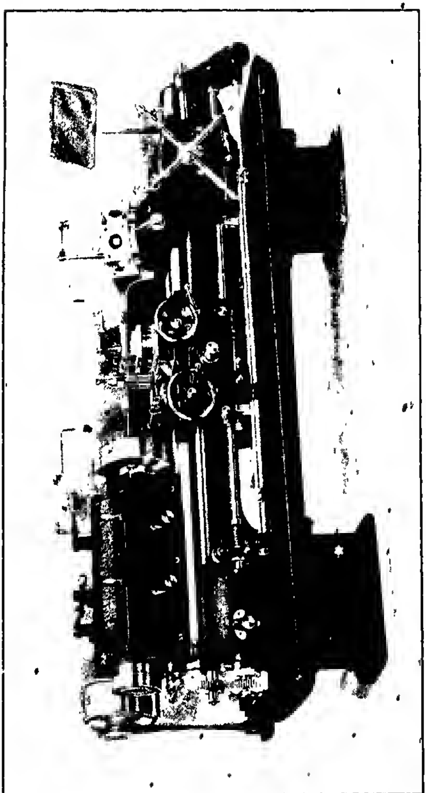


Fig. 51.—Combination turret lathe.

handle which works through a rack and pinion. The main turret, which is hexagonal, is set at an

angle of 15° away from the front of the machine, this arrangement making it easier to revolve the turret (which is by hand) and keeping the boring bars and tool-holders clear of the capstan handle.

The dead-stops for both the slide-rest and the turret saddle are arranged on a hexagonal rod disposed below the horizontal feed rod, which transmits the power for the power feeds to both elements. An automatic tripping gear is also provided to work in conjunction with the dead stops. The slide-rest is designed to work with both sliding and surfacing power feeds, and also with a screw-cutting feed obtained from a lead-screw.

When the slide-rest is equipped with a turret head, the latter is of the simplest possible form (as shown in the figure) and designed to carry any number of tools (usually comparatively plain) up to four. An ordinary tool-post is also provided sometimes as an addition to the above.

The other details of this machine are somewhat similar to those of the machine illustrated in Fig. 49.

The Engine Lathe with Turret Slide-rest.—Examples of this are given in Figs. 17 and 24. In each of these two cases the ordinary tool-clamping device or tool post is replaced by a simple turret head. In Fig. 17 the slide-rest is shown with a square open turret for four tools; whilst that shown in Fig. 24 has a circular turret for six tools. The turrets in cases like these are invariably revolved by hand.

The work of an ordinary engine-lathe (with self-acting sliding, surfacing, and screw-cutting feeds) can be done on machines of this type in addition to certain classes of work which is essentially turret-

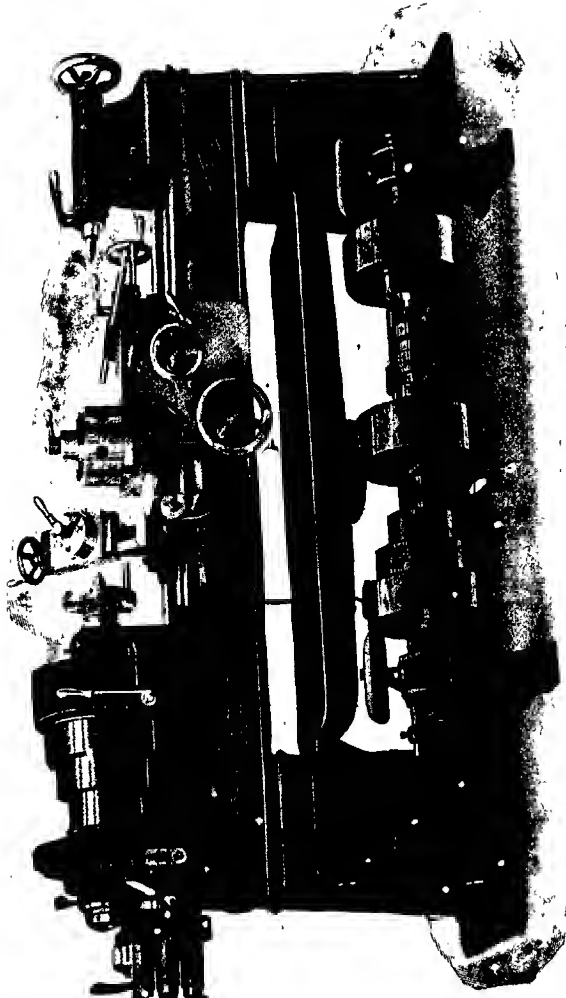


FIG. 52.—Universal monitor brass-finishing lathe.

lathe work, since the general details of such machines are those of engine lathes.

The Universal Monitor Brass-finishing Lathe. —This is illustrated in Fig. 52. It is a modification of the engine lathe with the turret form of tool holder

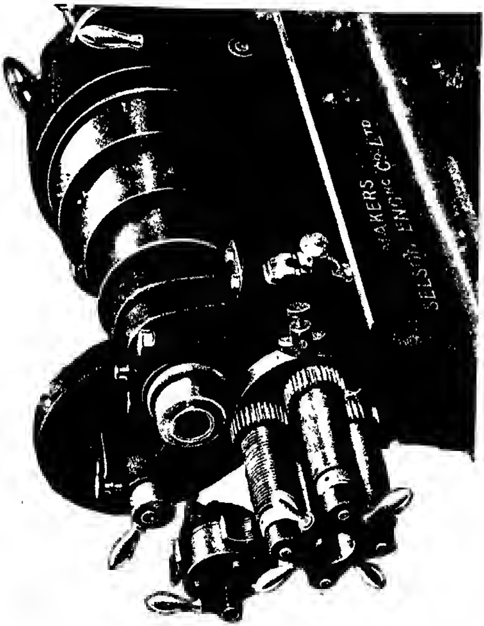


FIG. 53.—Headstock of monitor lathe.

applied to the compound slide-rest. It is equipped with a driving headstock and a tailstock similar to those of the ordinary engine-lathe type. This type of lathe is designed specially for the chasing of screw threads on brass parts. For this purpose copy

screws or hobs are provided to the number of four. These are shown in the end view of the lathe (Fig. 53). These screw copies are arranged in a revolving turret on the end of the machine, and any one of the four may be put into operation by merely revolving the turret on its horizontal axis. The design, however, is such that only the particular copy screw which is in action is in motion, the motion being derived directly from the main spindle of the driving headstock. Immediately behind the copy-screw turret another turret, which carries four dies or followers, is situated. Each of these followers is designed to work in connexion with one of the copy screws. This turret is mounted on the end of a non-revolving back-shaft, which transmits the translatory motion imparted to the die and turret to a chasing slide. This slide moves on the bed of the lathe in front of the ordinary slide-rest, and is equipped with a four-holed turret in which the chasing tools or hobs are placed. Both right and left hand screw-threads can be cut on this lathe, there being a reversing gear in the driving headstock. The ordinary slide-rest may be worked either from a copy screw or by hand, whilst, in some cases, an ordinary self-acting sliding feed is provided.

In the non-universal form of this type of lathe the copy screws and followers are fitted to the lathe singly, and hence any change of screw and follower which is required consumes a considerable amount of time.

The copy screws which are usually supplied with lathes of this type are for cutting the screw threads for gas, water, and steam pipes of 11, 14, 19, and 28 threads per inch.

CHAPTER VII.

VERTICAL LATHES.

THE vertical lathe, which is more popularly known as the vertical turning and boring mill, is one of the oldest of machine-tool types, though its use is not by any means as common as that of several of the newer types.

As has been already noted in a previous chapter, the working axis of a lathe of this type is vertical—hence its name—and the motions given to the tool or tools can be made in three directions usually, namely, the horizontal direction, the vertical direction, and any inclined direction between limits.

This type of machine-tool is well adapted for the machining (both internally and externally) of work which is of large diameter compared with its length; though it is quite possible to machine on it work whose diameter is not greater than its length. Generally speaking, however, the machine is totally unsuitable for long work. In fact it was originally designed for comparatively large-diameter work so that this could be better supported than is usually possible when a horizontal lathe is used. In this case, overhang of the work practically does not exist, whereas in the case of some classes of work machined on the horizontal lathe it is almost impossible to

eliminate overhang or mitigate its effects, both on the elements of the lathe and on the accuracy of the work.

The essential elements of a vertical lathe are: (1) the table; (2) the bed which carries the table; (3) the driving mechanism to the table; (4) the housing or housings; (5) the cross-rail which is carried on (4); (6) the saddle on the cross-rail; (7) the tool bar or slide which is mounted on the saddle; and (8) the tool holder, which is either of the plain or turret form.

The Table.—This is usually—though not quite always—circular in shape and arranged with tee-slots in its upper face. These slots are either radial or parallel or a combination of these, and are used to hold down either the work or the jaws or chucks or special fixtures which are used to secure the work to the table. The table is invariably well-proportioned and provided with massive radial ribs for reinforcing purposes. The table is mounted on a hollow cabinet bed, which is usually circular in section, and is driven through either spur, bevel, or worm gearing. In the case of the first, the table is provided underneath with a large internal or external spur-gear wheel, and this is put into mesh with a spur-gear pinion. In the case of the second a bevel-gear pinion drives a large bevel-gear wheel on the underside of the table. In the other case a large worm-wheel on the underside of the table is driven by a horizontal worm, either single, double, or triple-threaded. The form of drive in which the driving force is applied near to the vertical axis of the table is not a good one, and is not much used.

The spur-gear and worm-gear drives do not

produce any lifting tendency on the part of the table, as is characteristic of the bevel-gear drive, though in this case even the lifting tendency can be neutralized by the proper use of nether thrust bearings.

The downward thrust can be taken in four ways, these being (*a*) by an annular horizontal surface or pressure ring; (*b*) by an annular vee-groove; (*c*) by a central conical bearing; and (*d*) by a thrust ball-bearing. The methods (*a*) and (*c*) are the commonest.

Changes of table-speed can be made in four ways, as follows:—

1. By the use of ordinary cone-pulleys.
2. By the use of toothed gearing and gear-boxes.
3. By means of a variable speed electric motor.
4. By a combination of any of the above.

All the speed-changing mechanism is generally situated in the base of the machine, so that it is easily accessible and admits of ready operation.

On large machines the number of tables is universally one. On smaller machines the number is either one or two. The tables on the "duplex" machines may be mounted on either one bed or two; in the latter case, the two beds are invariably carried on the same base.

Housings.—These are the uprights which spring from the base or bed, and are the main supports of the machine. They are either cast solid with the bed of the machine or attached to it by means of studs or bolts and nuts. The former method is adopted only in the case of the smaller sizes in which only one housing or standard is employed.

Where there are two end housings, the second method is the one which is invariably adopted.

The number of housings is two on all machines which have a table-diameter of not less than 30 inches, and generally on all machines of the "duplex" type irrespective of the diameter of the table.

The housings are hollow, their external shape being either triangular (with a straight back) or parabolic (with a curved back). The latter form is more scientifically correct, and it is practically the only one which is employed by modern designers. Frequently the housings are open or centred, this form being adopted where it is desired and possible to reduce the weight without sacrificing strength and resistance to deflecting influences. Where width and exceptional stability are required—as in those cases where there is only one housing—the closed form has to be used. Very tall housings have special shapes.

A top-rail or beam is used to connect the two housings together and to increase the rigidity and stability of the structure. It is usually of [or channel section with intermediate cross-girts or ribs to strengthen it. With only one housing there is, of course, no connecting top-rail.

Each housing is provided, in the ordinary type of machine, with front and side square guiding surfaces, as shown in Fig. 54 (which illustrates a vertical turning and boring mill manufactured by Messrs. Webster & Bennett, Ltd., of Coventry). These surfaces are used as guides for the cross-rail in its vertical movements, and they are so arranged that the cross-rail can be gibbed or secured to each

housing rigidly. This securing or gibbing is effected by means of clamping plates and screws, or screws alone.

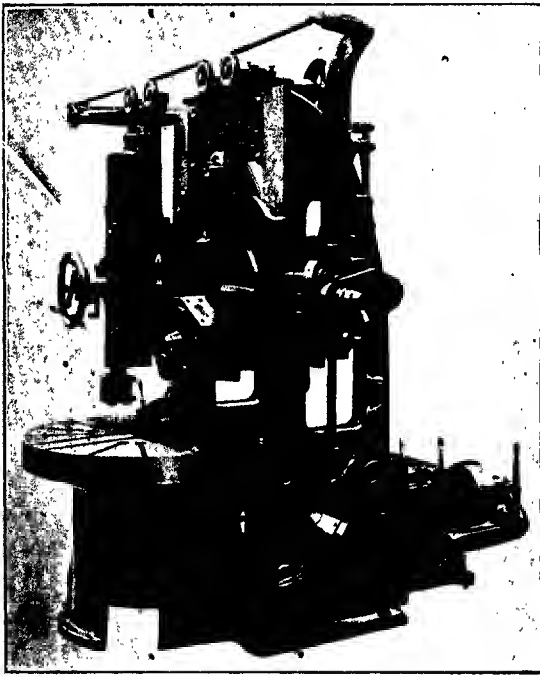


FIG. 54.—Turning and boring mill.

The Cross-rail.—This is either fixed or movable. In the former case it forms a head to the standard

of the machine, there being only one standard to the single-table type and one standard per table to the duplex type. An example of the latter is shown in Fig. 55. The movable form of cross-rail is employed in conjunction with two standards or housings, and these it completely embraces, as shown in Fig. 54.

The vertical movement of the second form of

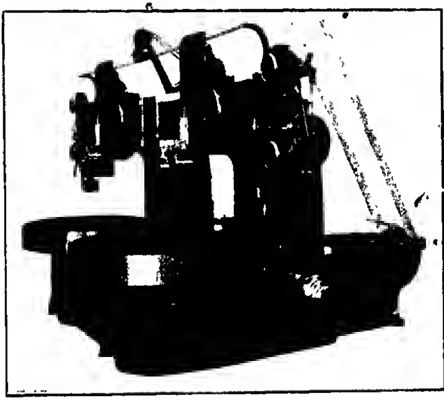


FIG. 55.—Duplex turning and boring mill.

cross-rail can sometimes be effected only by hand; in other cases only by power; whilst in some few cases both methods are available. In every case the principle of the screw is utilized. Two screws are used—one in a tee-slot in the front of each housing or on the side of the housing close in—these screws passing through nuts on the back of the cross-rail and terminating in bevel, worm, or spiral gearing at

the top of the housings. The two sets of gearing are connected together by a cross-shaft and also to a handle, handwheel, or crank-lever, or to the driving gear. In each case toothed gearing is employed to make the purchase reasonably large.

The Saddle.—This is carried on the cross-rail, which is provided with scraped horizontal and vertical surfaces to act as guides to the sliding saddle. The saddle can be secured rigidly to the cross-rail at any place in its length. On some machines (such as the one represented in Fig. 54) there are two cross-rail saddles, in which case, of course, the range of movement of each saddle is more or less restricted.

In the cross-rail are arranged a splined rod and a screw, each of which extends from end to end of the cross rail, and is horizontal. On the shaft a sliding bevel pinion is mounted, this being in mesh with a similar one situated in the tool-slide. The first pinion is arranged so that, whilst it is free to rotate with the shaft, it is constrained to move horizontally with the saddle.

The screw is used to feed the saddle along the cross-rail. It works in a nut which is secured to the back of the latter, so that rotation of the screw produces directly a translatory or traversing movement of the saddle.

Both the rod and the screw can be rotated by hand, each being provided with a square end on which a crank handle or lever is placed. Further, each rotation can be actuated mechanically through gearing, the power being derived from the ordinary driving mechanism of the machine. In many cases

a safety friction device is introduced into the gearing, so that, should the tool meet with an obstruction which it cannot remove, the gearing and the tool are protected.

Feed-gear boxes are provided on modern machines, so that feed-changes are considerably expedited thereby. Also the feeds, horizontal, vertical, and inclined, are automatic and reversible, whilst, in many cases, the feeding mechanisms are equipped with direct-reading indicators, by means of which it is possible to obtain very fine changes of feed.

The Tool-slide.—This is usually arranged in or on a swivelling clamp-bed—which is rotated either directly by hand, as in small machines, or through gearing (to increase the purchase), as in the largest machines—so that it can be placed at any angle to the horizontal. The clamp-bed is secured to the saddle by means of a number of bolts, ranging from two to six, and is graduated in degrees. Any angle can thus be readily read off. In some special forms of vertical turning and boring mills the tool-slide is of the non-swivelling variety, however, and only vertical and horizontal movements are possible; whilst in some very special forms the only movement possible is the vertical movement. In the first of these latter cases certain inclined feeds are obtainable by compounding the horizontal and vertical movements, but this is not often done, a machine of the ordinary type being usually employed for tapered work, whether internal or external.

The tool-slide may be either screw- or rack-driven, but, in each case, the power feed is derived directly from the splined shaft in the cross-rail and through

the bevel gearing in the saddle already described. The axis of swivel of the clamp-bed is always coincident with the axis of the short shaft which, being at right angles to the cross-rail shaft, carries two of the four bevel pinions in the gear. The fourth bevel pinion drives either the rack-pinion or the nut of the longitudinal-feed screw of the tool-slide, and it is so disposed that, when the tool-slide is swung round through an angle, it rolls round the third bevel pinion. Thus it is always in mesh with the latter, and the gear connexion is never broken.

When the drive is through a rack and pinion—which is the commoner arrangement—the tool-slide can usually be raised or lowered by hand in either of two ways. The first is by means of the splined shaft in the cross-rail, either end or both ends of this being squared to allow loose crank handles to be placed on them. In certain designs of machines of this type non-removable handles are employed, these being connected to the shaft through either toothed or friction clutches. The second way is by means of a handwheel or handle which is mounted directly on the pinion shaft in the tool-slide and connected to the bevel-pinion shaft by a friction clutch, which has to be put into operation when the power feed is put into action. The latter of these two methods is always possible on machines with cross-rail and travelling tool-slides, but not so the former, which is only possible on certain machines. On machines without cross-rail it is only a modification of the former method which is available. Gearing is occasionally introduced to increase the effect of

the effort at the hand-wheel and so reduce its magnitude.

When the drive is by means of a screw and nut, the hand adjustments of the tool-slide have, on small machines, to be made *via* the cross-rail shaft, whilst on large machines it may be made in that way or from a hand-wheel which is connected to the feed-screw through gearing in or on the tool-slide.

The number of ordinary tool-slides provided on a machine vary from one to three per table. Very rarely is the latter number exceeded. Each slide is connected by means of a chain to a balance weight which serves to take the weight of the slide off the rack-pinion or feed-screw and so reduce the effort which is required to raise the slide. The balance-weight arrangements are of two kinds: in one arrangement each slide has a separate balance-weight; in the other arrangement all the slides are connected by one chain to one balance-weight. The latter arrangement is the one which is usually adopted in the case of cross-rail machines when there are two or more tool-slides and saddles. In each case the chains are carried over and round pulleys mounted on the tool-slides and on the frame of the machine as shown in the two figures. The chain may be arranged so that both ends are attached to fixed points or arms and the balance weight suspended from the middle of the chain, or with only one end fixed and the balance-weight attached to the other end. The former arrangement is illustrated in Fig. 55, and the latter in Fig. 54.

The Tool-holder.—This is fitted on the lower end of the tool-slide, and may be of either the plain screw-

clamp type or the turret-head type. Both forms are shown in Fig. 54. The turret-head is generally designed to carry five tools, and is revolved and locked in position by hand. The tools carried are of the reamer and boring-tool type.

Where several different operations have to be performed on the same piece of work, and these can be done with one setting, the turret-head holds tremendous advantages over the plain type of holder, in which not more than two tools can be held at any one time, and these require special setting with respect to one another.

Additional Tool-slides.—These are only provided on machines which are of more or less special design. They may be disposed in two different ways.

The first of these involves the provision of an extension to the ordinary cross-rail in the form of a rail running at right angles to it, and being capable of travelling on it. This extension (which may have a length equal to one-half of that of the cross-rail proper) is secured to an ordinary cross-rail saddle, and supported also from the head of the machine. The additional tool-slide travels on this rail. This arrangement allows the table of the machine to be thrown outwards, thus increasing its capacity; and it also facilitates boring operations when the diameter of the hole is small compared with the external diameter of the work.

The second disposition of an additional tool-slide is on the front of either or both of the housings or standards. This arrangement is suitable in cases where external machining (i.e. turning) has to be done on the lower part of a piece of work whose

upper part is much wider than the lower and prevents the use of a tool from above.

Additional Boring-bar Support.—In the latest type of vertical lathe—viz. the type designed for the turning and boring of steam-turbine drums—a central boring-bar support is an intrinsic part of the design. This support is made very massive to resist all deflecting influences and is erected on the base of the machine in the centre of the table which, in this case, is hollow. The boring-bar or tool is secured on this support, and the mechanism is of such a design that the bar or tool may slide in the support, but this movement is rigidly vertical, no rotation being at all possible. The use of this support renders the use of a boring-bar or tool in the ordinary tool-slide, with a necessarily large amount of overhang, quite unnecessary. In fact it is a question whether the latter method would be at all possible in cases like this, where the length to be bored may be anything up to 10 feet.

CHAPTER VIII.

SPECIAL LATHES.

The Bench or Precision Lathe.—This is a lathe of a comparatively small size, and is designed for exceedingly fine work. Lathes used by watch-makers belong to this class, as does the lathe represented in Fig. 56. This is a Drummond lathe, and is designed for plain turning, surfacing, screw-cutting boring, and milling. The bed, which is of cast iron, is of hollow circular section, this section being obtained by grinding, the limit of error being 0·0001 inch. This bed is fitted in the two standards of the machine and held rigidly therein. The driving headstock is part of the left-hand standard, the spindle being of steel, one inch in diameter, and ground true. The bearings are adjustable and made of the best hard gunmetal. The speed cone has three steps for a flat belt, and no back-gearing is provided. The loose headstock is fitted on the bed and is secured thereto by a screw. It is provided with a set over adjustment, so that it can be used to support work which is slightly tapered. The slide-rest consists of a saddle, which completely embraces the bed, and a superimposed plate which carries the tool-holder. The upper surfaces of both the saddle and the top plate are formed with tee-slots, these being used to

hold down pieces of work which have to be milled.

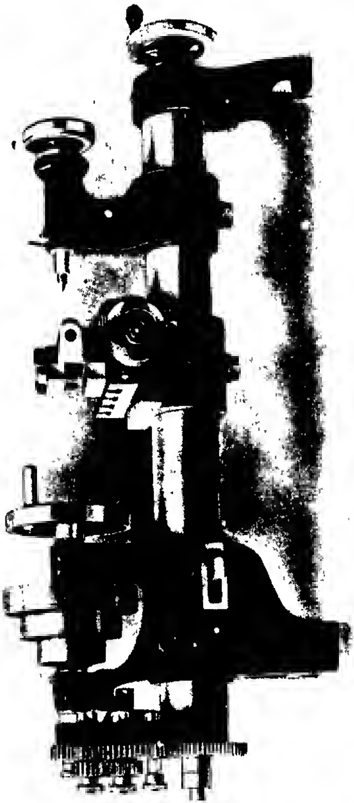


Fig. 56.—Drummond precision lathe.

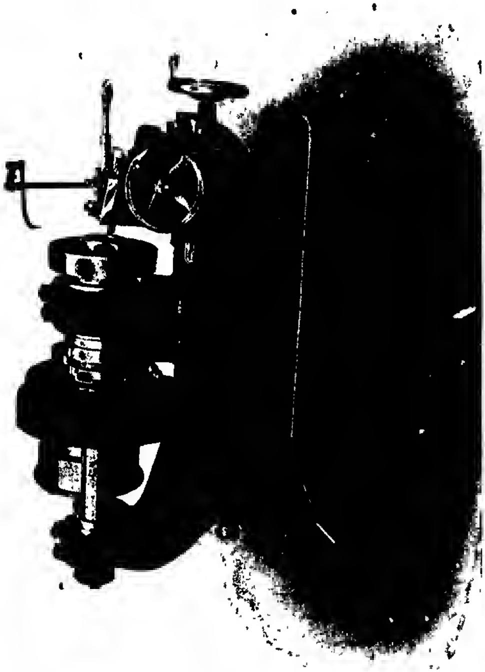
The top plate consists of two parts, the upper one of which can slide in vee guides on the lower. A

screw, which terminates in a small hand-wheel, is used to obtain the slide movements. The lead screw—which is machine cut—is fitted inside the bed and runs central with it from end to end. The clasp-nut is connected to the underside of the saddle and is always in engagement with the screw. A handwheel on the end of the screw enables the saddle to move along the bed by hand. A train of change-gear wheels connects the lead-screw to the driving spindle for the sliding power-feed and for screw-cutting. A reversing gear is also provided to enable the direction of rotation of the lead-screw to be reversed.

Nut-facing Lathe.—One form of this type of lathe is indicated in Fig. 57. It is a Lang lathe, and designed only for the facing of nuts. When the lathe is in operation, the nut to be faced is placed on the mandrel and run full on by power. After the facing operation has been completed, the nut is run off by power by the movement of a handle in front of the spindle. Thus the lathe does not require to be stopped and started periodically. This is a decided virtue. The slide-rest is placed on a short length of bed and arranged with two movements, longitudinal and transverse. The tool-holder carries four tools, viz. one roughing tool, one finishing tool, one chamfering tool, and one burr-removing tool. These are put successively into action by means of a handle or lever which is attached to the tool-holder. A stop is provided for each movement of the tool-holder slide, so that nuts can be finished to a standard size.

The Backing-off or Relieving Lathe.—The

chief work of this type of lathe is the forming and backing-off or relieving of milling cutters of the constant-profile, formed variety. The principal



part of its mechanism is, therefore, that which enables it to be used for this kind of work. It is generally a fully-equipped lathe for tool-room work,

and can be used for all ordinary engine-lathe operations. It should, however, be used for the latter as little as possible.

The principle of action of the backing-off mechanism is that of the cam, a reciprocating motion of the tool and tool-slide being derived from a constant-speed rotatory motion of the cam or cams. In one case this latter motion is obtained from an additional fixed back-shaft; another from a fixed front-shaft; and in a third from a telescopic front-shaft in conjunction with universal couplings as shown in Fig. 58. With the first two methods, the ratio between the instantaneous speed of the cutter blank and that of the tool is invariably constant; that of the third case undergoes slight changes per revolution of the telescopic shaft, these changes being due to the action of the two universal joints.

The Duplex Axle or Shaft-turning Lathe.—The feature of this lathe is to be found in the fact that both centres are dead (i.e. non-rotating) centres, and not, as in the ordinary lathe when the two centres are used, one dead and one live. One form of this lathe (as made by Messrs. Pollock & MacNab, of Manchester) is represented in Fig. 59.

The driving head is mounted on the middle of the bed, whilst the two loose-headstocks, which carry the centres, are placed one on each side of this head. The spindle of the driving head is hollow and gear-driven, the gear-wheel on the spindle being completely enclosed. The driving power is received in this case from a single-driving pulley, and speed-changes are effected by means of gear changes, the gear wheels for such changes being enclosed in a box

formed in the left-hand bed standard. The gear changes are made through the medium of the levers

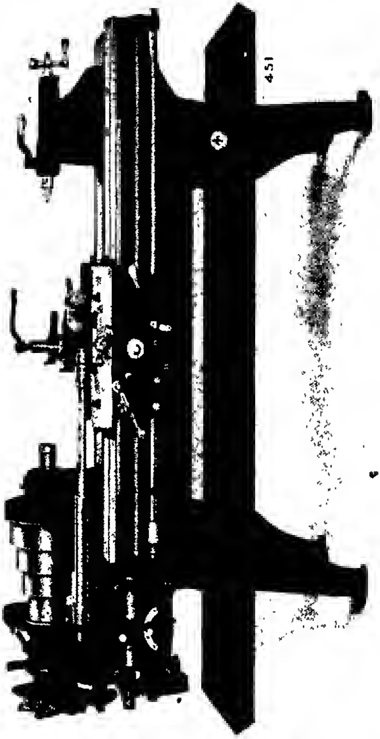


FIG. 58.—Backing-off or relieving lathe.

shown in the figure. From this box the power is transmitted through a shaft situated inside the bed and running parallel with it. On this shaft is

mounted the gear wheel which is in mesh with the

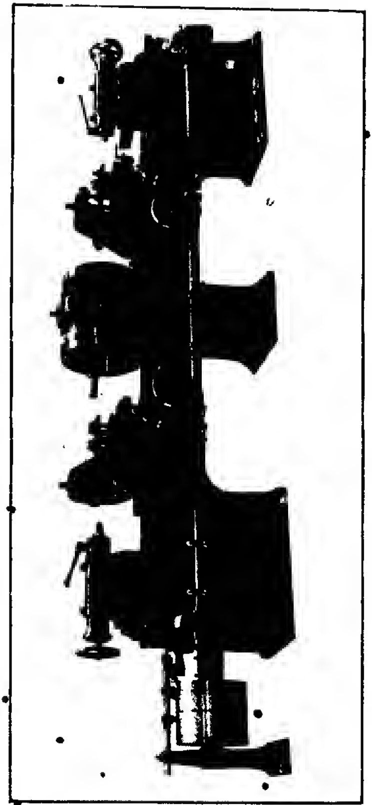


Fig. 59. —Duplex axle-turning lathe.

gear wheel on the spindle of the driving head. In some forms of this kind of lathe, a cone-pulley drive

is used, and speed-changes are made in the usual manner, which involves the shifting of the driving belt.

The loose-headstocks are mounted on saddles in this case, the left-hand one being equipped with a cross-slide, so that it can be moved out of line with the driving head for the purpose of getting the work in and out of the lathe. In some cases this movement is not possible, and one of the loose-headstocks has to be moved on the bed longitudinally prior to any movement of the work in or out of the lathe.

The work is threaded through the hole in the spindle of the driving head, supported at each end by a centre, and driven by a double driver of the Clements' type through a carrier. The drive is thus a balanced one, and possesses no tendency, whatever, to throw the work out of truth.

The lathe is equipped with two slide-rests, which are frequently of the compound type, though, in some cases, the top-slide is dispensed with and all longitudinal movements of the tool are obtained by moving the whole slide-rest. The form illustrated is, however, the better one of the two. The power feed to each slide-rest is derived from either a splined feed shaft or a lead-screw. In the latter case, usually, either two screws of different hands or one screw with two different threads is used. The shaft or screw is driven either from the spindle of the dividing head by means of an eccentric and ratchet, or from the central shaft in the bed through toothed wheel gearing. The feed obtained by the former means is intermittent; that obtained by the latter is continuous and, therefore, preferable. A safety slipping clutch

is mounted on the shaft to protect the gears, and to prevent overloading. Also a change-feed gear-box is provided, so that the feed changes are effected by the mere movement of a handle or lever.

The slide-rest feed aprons are somewhat similar to those of engine lathes, but the mechanisms are so designed that the two longitudinal power movements are in opposite directions towards the driving head.

The Double Railway-wheel Lathe.—The general design of this will be readily understood from a perusal of Fig. 60. Its essential parts are two driving headstocks, placed *vis-à-vis*, and two slide-rests of the compound type, so that it is possible to turn two wheels on their axles simultaneously without subjecting the axles to torsion, to turn and bore two tyres at the same time, or to turn a wheel or bore a tyre on one faceplate whilst bossing or boring a wheel on the other.

The face-plate of the left-hand headstock is driven directly either by a belt working on a cone-pulley, or by an electric motor working through toothed gearing. The face-plate is gear driven, as shown, all shaft torsion being thereby eliminated. The face-plate of the right-hand headstock is driven from the one on the left through a driving shaft which runs inside the bed, and which carries the two driving pinions. This driving shaft is connected to the cone-pulley or motor by ordinary toothed gearing, and speed changes are effected in the usual ways.

Each slide-rest carries three slides, the middle of which (being a longitudinal slide) can be driven from a front feed shaft by means of a chain and ratchet. The feed in this case is, of course, inter-

mittent. Further, the whole slide-rest can be moved

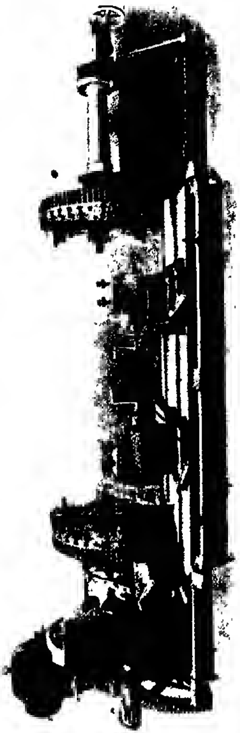


Fig. 60.—Duplex wheel lathe.

on the bed, but when the machine is in actual operation, the slide-rest is bolted down securely on the bed.

Lathes of this type will take in driving wheels of diameters up to 8 feet.

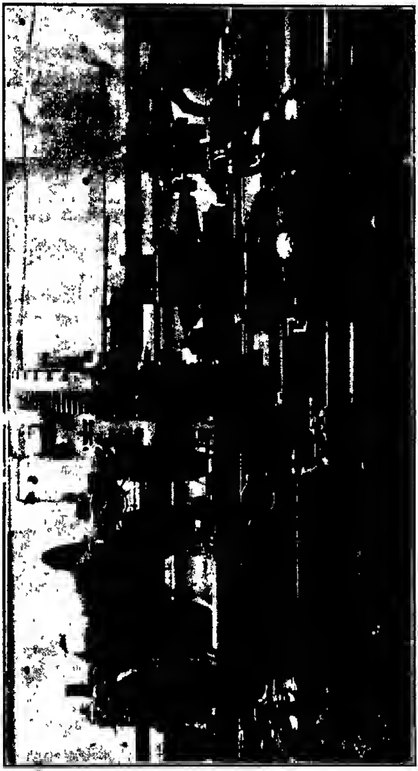


FIG. 61.—Turbine-rotor turning lathe.

Lathes for turning long lengths of shafting are also made with a double drive, so as to reduce the amount

of torsion induced in the work and to reduce its effects

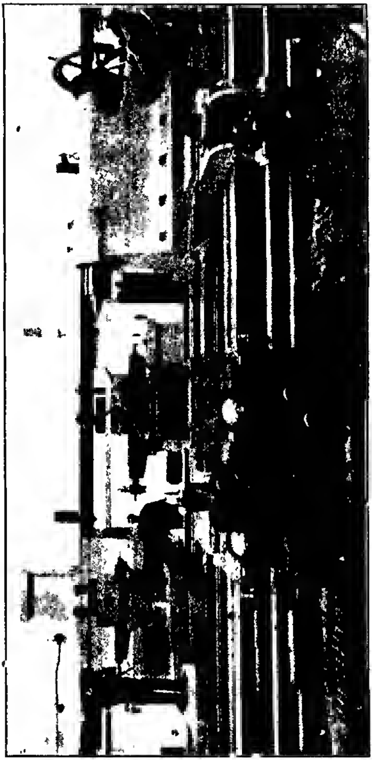


FIG. 62.—Turbine-rotor turning lathe.

on the accuracy of the work. Any number of slide-rests up to 4 may be used.

Turbine-rotor Turning Lathe.—Two views of a

large lathe designed for the turning of turbine-rotors are shown in Figs. 61 and 62. On this machine (made by the Armstrong Whitworth Co. of Manchester) work up to 16 ft. 6 ins. in diameter and 50 ft. in length can be dealt with in an expeditious manner. The height of the centres above the tops of the bed is 9 ft., though this can, when necessary, be reduced to 5 ft. The view shown in Fig. 61 is of the driving headstock; that shown in Fig. 62 is of the loose headstock.

The bed consists of five semi-box sections, as shown in Fig. 63, connected together by a number of cross-

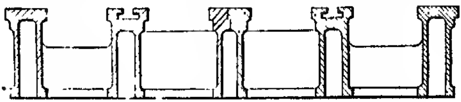


FIG. 63.—Bed of turbine-rotor turning lathe.

girders or ribs also of box section. Such a bed must have a concrete foundation of a depth of not less than 6 feet.

The tee-slots in the shears of the second and fourth sections carry the bolts which hold the driving and loose headstocks down on the bed.

The driving headstock is cone-pulley actuated, and the face-plate gear-driven.

The loose-headstock mandrel can be fed in or out of the barrel either directly by means of the large hand wheel, or through the worm-gearing shown. This headstock is mounted on a saddle, which can be moved along the bed by power transmitted from the front feed-shaft through bevel-gearing to a rack-pinion.

The slide-rests are four in number. Each carries three slides, the upper two of which are mounted on

a swivelling clamp-bed, this arrangement admitting of the turning of short tapers.

The total weight of this machine is about 300 tons, and an electric motor of 80 B.H.P. is required to drive it. The speed arrangements are such that the range of face-plate speeds is from 0·25 to 20 revs. per min.

Three-spindle Turning and Forming Lathe.—This is a machine for the multiple production of parts which require comparatively plain machining. It is different from the turret-lathe type inasmuch as in this machine three pieces of work can be machined similarly at the same time by means of three fixed tools, whilst in the other case, usually only one piece is operated on at once, and that by a rapid succession of widely different tools.

This machine (Fig. 64), which is made by the Selson Engineering Co., Ltd., is suitable for the machining of small parts included in motor-cars, bicycles, guns, looms, machine-tools, sewing machines, etc.

The driving headstock carries three spindles which derive their motion from a stepped-cone pulley through toothed gearing. Three steps are provided on the cone, so that, when the headstock is fitted with back gearing, six spindle speeds are available. The centres in the driving spindles are of the non-rotating type, so that perfect alignment is always maintained.

The loose-headstock is equipped with three mandrels and centres which are immediately opposite the centres in the driving headstock. Each mandrel is fitted in a slide which can be set over slightly for taper-turning. The three slides are super imposed

successively on each other and on the saddle which

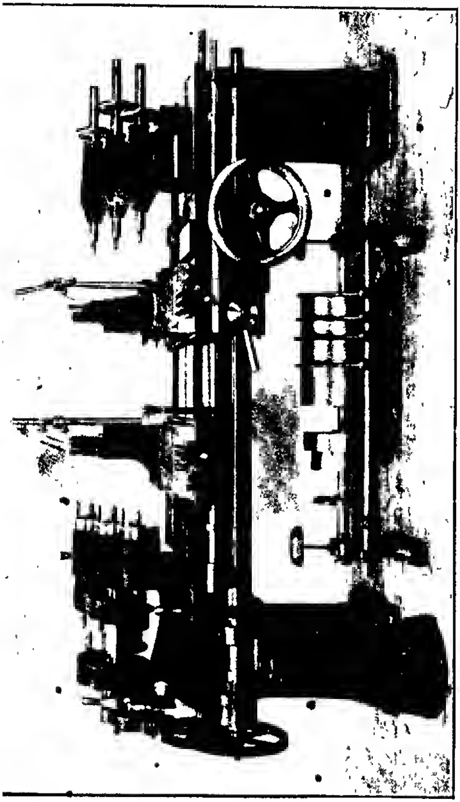


Fig. 64.—Three-spindle turning and forming lathe.

rests on the bed; and they can be moved on or

across the bed as one unit, and held in any position.

The angle between the plane which contains the axes of the three centres and the horizontal is about 30°.

The slide-rest is equipped with a triple tool-rest, which carries three tool-posts. These three posts can be fed into the work transversely either separately or as a complete unit; whilst, further, each tool can be swivelled through a complete revolution independently of the other two. The slide-rest can be moved along the bed by hand through a hand-wheel and rack-pinion, and by power through a lead-screw.

For the forming operations, a forming guide or bar is employed. This is placed at the back of the lathe, and the tool-rest is pressed against it by means of a heavy weight. The contact between the bar and the tool-rest is a roller contact.

The Automatic Screw Machine.—This is a logical development of the turret lathe. It is a machine for the rapid production of small parts, the production of each part involving a number of different tooling operations. The parts are usually made from bar stock, and the tools for the different operations are held in a turret head, which may have either a vertical or a horizontal axis. The great difference between this machine and the turret lathe is in the control of the turret head or heads, and in the control of the arrangements for feeding-in the stock. On this machine both controls are mechanical or automatic, the only hand manipulations necessary being in regard to the setting of the tools and the replenishing of the stock. This automatic control is

secured by means of cams, which are usually in the form of fairly large and wide drums, on which cam plates made of hardened steel are secured; it is against the edges of these that the rollers on the cam levers press.

The general form of this machine is shown in Fig. 65, which represents a motor-driven automatic screw machine.

Small parts other than screws can be produced on this machine, though it owes its name to the fact that it was first employed for the manufacture of screws.

The Automatic Lathe.—This is a machine for the comparatively plain tooling of work which is held on centres or centred mandrels performed purely automatically. The Fay lathe is an example. This is made by the Jones and Lamson Machine Co., and an idea of the general form of it can be obtained from a perusal of Figs. 66 and 67, which represent front and back views of the machine.

The essential elements of this machine are a driving headstock, a loose-headstock, a slide-rest, a swivelling-rest, and controlling cams. These are mounted on a bed of very heavy construction.

The driving spindle is a stiff, heavy iron casting, with long bearings, which also are of iron. It is worm driven, speed changes being made by the use of a two-speed countershaft and a three-stepped cone driving pulley, which has its axis placed at right angles to that of the driving spindle, and which drives the worm directly. The worm wheel is of high-grade phosphor-bronze, and the worm is of hardened steel; this is in close agreement with the best modern practice.

The work-drive is balanced, a Clements' driving plate being employed, so that heavy cuts may be taken without causing the work or mandrel to be

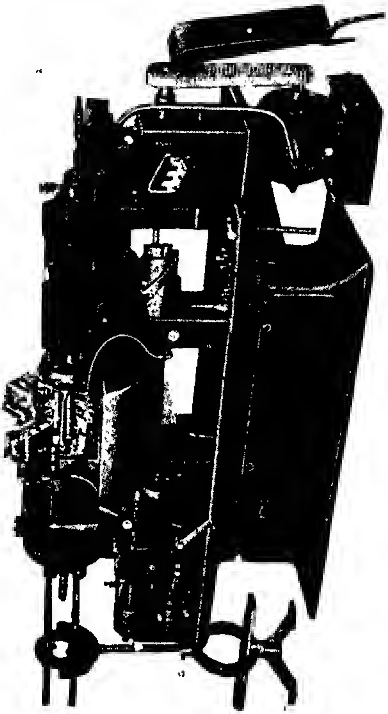


FIG. 65.—Automatic screw machine.

deflected, as is often the case when the drive is a single point unbalanced one.

The loose headstock is made solid so that its

rigidity is as great as possible, a condition which

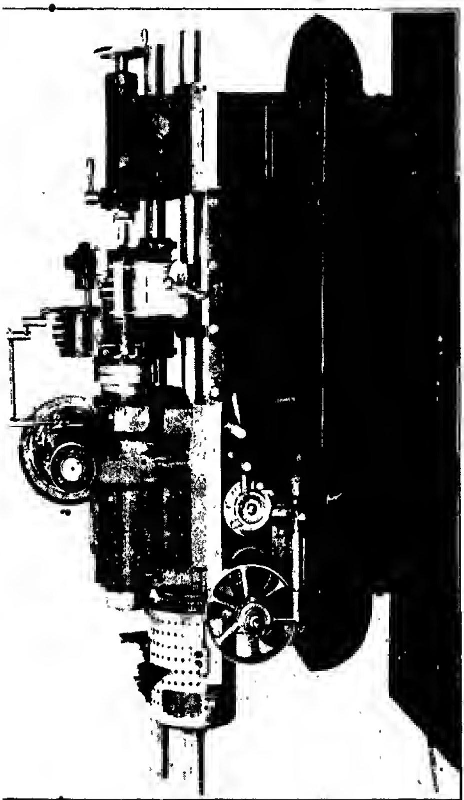


Fig. 66.—Fay automatic lathe.

would not be realized if the headstock were of the set-over type and provided with a sliding joint.

Tapers can be turned on this machine, but this kind of work is provided for in other ways.

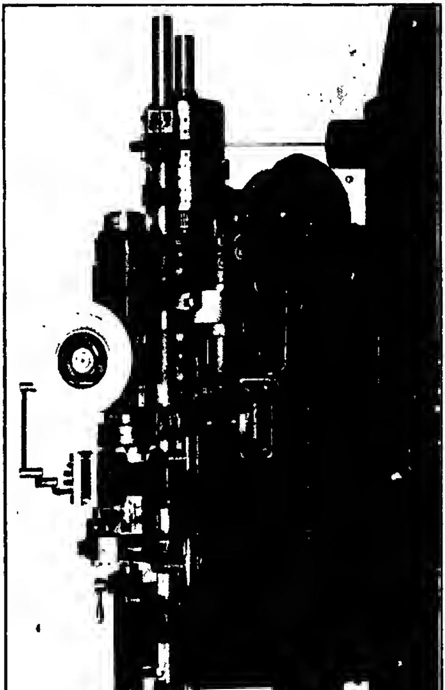


FIG. 67.—Fay automatic lathe.

The slide-rest is carried and permanently clamped

on a heavy steel bar of circular section, and on ways of the ordinary type. This bar connects the driving and loose-headstocks, thus adding strength to the bed. At the front of the bed the slide-rest is supported on a hardened plate which is part of a square steel bar, known as a "former bar". This former bar carries on its upper face a former, the chief function of which is to swing the slide-rest about its central support when a shaped contour has to be turned on work. The former is also used to control the movements of the slide-rest when facing or recessing operations have to be performed, whilst a still further use is in the dropping or relieving of the turning tools on the return stroke in order to preserve the evenness of the finished surface of the work. The former-bar movements are controlled by cams on the periphery of the drum at the headstock-end of the machine. The movements of the central bar which carries the slide-rest are controlled by cams on the inside face of the same drum.

The swivelling rest or back arm is mounted on a heavy steel bar and secured rigidly to it. This bar is parallel to the central bar, and its longitudinal movements are controlled by cams on the periphery of the drum. In addition to this movement it has a swivelling or oscillatory motion, which it derives from a heart-shaped cam (Fig. 67). This cam is positively geared with the cam drum. The weight which is shown in this figure keeps the bar roller on the cam. This rest is normally used for straight facing, whilst the other rest is normally used for plain sliding. A supplementary back-arm is also provided.

The cam drum derives its motion from a small pulley which is mounted on the driving-pulley shaft. The drive is continued through a belt working on a pulley on a shaft which carries a worm, and this worm actuates a worm-wheel cut directly in the cam drum. This is the direct drive, and is used to return the rests; the feeding drive is through gearing (Fig. 66), which is put into and out of action by means of clutches. The former drive gives a higher speed of movement than does the latter.

The tool boxes on the two rests are of massive construction, and carry from 8 to 12 set-screws each for holding the tools in position. A maximum of 4 tools can be held in the tool-box of the front rest, and a maximum of 6 in the back-rest. Thus 10 tools can be arranged for simultaneous operation.

The automatic lathe is essentially a second-operation machine—that is, one in which work, which has been partly machined from the rough casting or forging in a chucking or similar lathe, can be finished. This is specially true in regard to bored work.

CHAPTER IX.

LATHE ACCESSORIES.

1. CENTRES.

MODERN lathe centres are made of high-grade cast steel containing a medium percentage of carbon, and hardened and tempered. They are generally finished to size by grinding, and trued up and sharpened. Before the introduction and development of the modern abrasive processes, it was the usual practice to soften a lathe centre, whenever it required truing up, and do the truing up with a turning tool and file. The centre had then to be rehardened and retempered, there always being present in these operations the risk of distorting the centre and robbing it of the truth given to it in the machining operation. To-day they are trued up either *in situ* by means of a portable grinder or in a grinding machine fitted with a special attachment.

An ordinary engine lathe carries two plain centres, one—a live or rotating centre—in the driving-headstock spindle, and the other—a dead or non-rotating centre—in the loose-headstock mandrel. Each is provided with a tapered shank which fits in a tapered socket, and is held therein by a purely frictional force. The total taper which is adopted for the centre sockets and shanks varies fairly considerably,

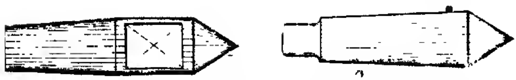
ranging from 1 in 32 to 1 in 8. These are the extreme limits, however, the usual taper adopted lying between 1 in 24 and 1 in 16. The Morse taper, which is approximately 1 in 20—though this varies with the number and length of the taper—is very common. In any works it is very desirable to have all the lathe centres with a common taper so that they will be interchangeable.

The point angle of lathe centres varies from 60° to 90°, such angles as 75° and 80° in addition to the above being in use. This is the total angle measured on both sides of the centre axis. The blunt angle of 90° is the old English angle, whilst the fine angle of 60° has been the standard American angle for years. There does not appear to be any real reason why such a blunt angle as 90° should be used, even in the case of the heaviest lathes, and, hence, standard English practice is gradually undergoing a change, and the 60-degree angle is being slowly adopted for light work. Probably another reason for this is to be found in the extreme facility of forming centre-holes by means of combined centring and countersinking drills, which are not made for 90-degree holes. For heavy work the use of a 75-degree centre is recommended.

One form of the ordinary or plain centre is represented in Fig. 68. The tapered shank and the point are connected together by a parallel body, on which two parallel flats are machined. These flats are used in conjunction with a spanner or wrench to twist the centre out of its socket.

Another form of the plain centre is shown in Fig. 69. On this form there is no parallel connecting

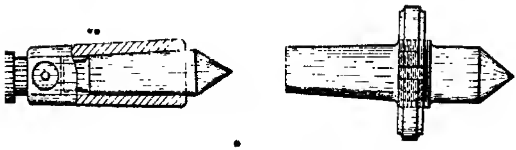
body, the shank and the point merging into each other. Centres of this form have to be knocked out of their sockets, either by means of a bar (in the driving-headstock spindle) or by means of the loose-headstock mandrel screw. To prevent the small end of the shank from being damaged and burred over (and so



FIGS. 68 and 69.—Plain centres.

affecting the fitting of the shank in the socket), a parallel tail is formed on the centre to receive the blows or the application of the ejecting force.

In Fig. 70 is illustrated an ejecting device in which a centre of this form is used. The centre is carried in a tapered sleeve which fits in the spindle socket. In the smaller end of the sleeve is fitted a loose plug which is prevented from slipping out by a small



FIGS. 70 and 71.—Devices for ejecting centres.

pin. The head of this plug receives the blow, and transmits the force to the centre. In this way the centre is ejected without damage to itself.

Another way of ejecting a centre involves the use of a tommy bar or wrench in a diametral hole in the shank of the centre, as shown in Figs. 86 and 87.

The centres of large lathes are usually ejected by means of nuts, which work on threaded shanks

(Fig. 71). The nuts used are either of the hexagonal or fluted circular type. To eject the centre, the nut is screwed up against the nose of the spindle or mandrel, this action producing the desired outward movement of the centre.

The reduced centre, as represented in Fig. 72, is to support work of a small diameter. It is only used

FIG. 72.—Reduced centre.

FIG. 73. Enlarged-point centre.

in the loose-headstock as a dead centre, and its form is such that the tool, when working at that end of the work, is not fouled by it.

In Fig. 73 is shown a centre with an enlarged point. This form of centre is suitable for the support of work of moderate diameter, whose ends require facing. If the diameter of the mouth of the centre

FIG. 74.—Half centre.

FIG. 75.—Ball centre.

hole in the work is greater than the diameter of the shoulder of the centre, it is always possible to face the end of the work completely. Another point to observe in connexion with this form of centre is that the amount of grinding involved in the truing-up and sharpening of the point is much less than with a full-point centre.

The half or cut-away centre, which is represented in Fig. 74, is another form of centre which is available

for this kind of work. The point of the centre is almost reduced to one-half by the removal of the metal on one side of a plane which is parallel to the axis of the centre. When the centre is in actual use, the cut-away part is on the tool side—i.e. on the front.

A spherical form of centre is shown in Fig. 75. The point of this centre is provided with a spherical end. The centre hole in the work when such a centre is used should, perferably, be also spherical—say, hemispherical—though, if the operation to be performed on the work is a parallel-turning or screw-cutting operation, the conical form of centre hole would serve. For taper-turning with the loose-headstock

FIGS. 76 and 77.—Cup centres.

set over, however, hemispherical centre holes should be used as, by this means, all errors due to axial obliquity are avoided.

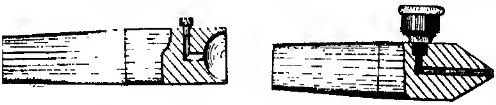
Cup centres are not provided with pointed ends, but with centred ends. The form shown in Fig. 76 contains a plain conical hole (with an included angle of 60°). It is serviceable in cases where work of such a small diameter that it cannot be satisfactorily centred, has to he supported. The end of the work is placed in the hole.

A slightly different form is indicated in Fig. 77. The hole in this consists of two parts, a tapered part (having an included angle of 60°), and a smaller parallel part. In fact the hole is exactly like the

standard centre holes formed in the ends of work. Pointed work, like twist-drill blanks, is supported in such a centre.

Another form of cup centre (with a hemispherical hole) is represented in Fig. 78. It is suitable for the support of medium-sized work with rounded ends. A variation of this is in the substitution of a curve of another shape for the sphere.

The lubrication of centres is an important matter, since the pressures to which they are subjected may be considerable, and to give satisfactory service they must necessarily be capable of being used without either scoring the centre-holes of the work or being



Figs. 78 and 79.—Lubricated centres.

themselves scored. This, of course, only applies to non-rotating centres, running or live centres ordinarily being non-lubricated.

The usual method of applying the lubricant—which should be a high-grade machine oil—in cases where the centres are solid is to put a little oil in the centre-hole of the work before the centre is put in, and to replenish this by slightly easing the centre back and dropping or pouring oil on the centre. In the case of large centres and heavy work, a solid form of lubricant, such as tallow, is used initially in the centre hole. This gradually melts as the temperature of the centre rises, and it is supplemented by machine oil, the flow of which to the point of the

centre is assisted by one or more lubricating channels or grooves cut in the surface of the hole.

It is possible, however, to supply the lubricant in other ways. One way is indicated in Fig. 78. This involves the use of two small holes in the centre, one parallel to the axis, and the other at right angles thereto and running out into the shank. The two holes meet in the centre and form one continuous channel from the shank to the point or hole of the centre. A plug is used to keep dirt out of the channel. Ordinary machine oil is fed into the channel periodically.

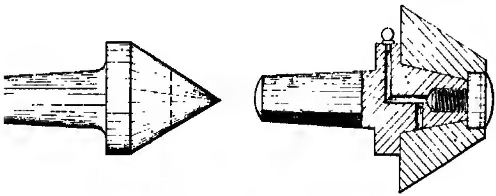
Another method is to have a narrow longitudinal slot in the point of the centre, this slot running into the shank where the oil is supplied. The edges of the slot have to be slightly rounded to prevent them from having a reaming effect on the surface of the centre hole.

An improved method of lubrication is represented in Fig. 79. In this method a screw-down forced-feed lubricator is used in conjunction with a right-angled channel leading to the centre point. If thick lubricant is used, this method gives satisfactory results.

Another method—though one which is not always possible—is to supply the lubricant by means of a forced feed through a longitudinal channel in the headstock mandrel and centre, the lubricator being mounted on the tail-end of the mandrel.

Large centres have to be used for the support of pipes and other pieces of hollow work, whose internal diameters are greater than the diameters of standard centres. These are of two kinds: the non-

rotating, solid kind, and the rotating kind. The general form of the former is indicated in Fig. 80. The point may be either a full cone or a truncated cone (as shown by the dotted lines), though there does not appear to be any scope for the apex of the full cone. The use of this kind of centre, however, often produces objectionable results, especially when the bore of the work is not quite smooth and the end not quite square with the axis, as is frequently the case with rough castings. In such cases the work does not ride evenly on the centre, and excessive frictional resistance is thereby set up, heating



Figs. 80 and 81.—Pipe centres.

and scoring of the centre, and heating and expansion of the work thereby resulting.

The rotating centre possesses none of these undesirable features. It exists in two forms, which are represented in Figs. 81 and 82. The plain form, which is shown in the former figure, consists of a steel body with a tapered shank and a tapered or parallel point, on which revolves the point proper. When the body-point is parallel, the thrust is received by one or two washers, whilst, in the form indicated, it is received partly by the conical surface and partly by the normal thrust surface of the body. The journal and bearing

surfaces are lubricated in the manner shown, lubrication involving no alteration of the adjustment of the centre. A screw prevents the point from leaving the body.

The form shown in Fig. 82 is a decided improvement upon the above. The thrust in this case is received by a ring of balls, and the frictional resistance is thus considerably reduced.

Vee-centres are used for supporting work against the cutting action of a drill or similar tool when the latter is driven and the work is held stationary. They are generally held in the loose-headstock mandrel and the vee runs at right angles to the lathe

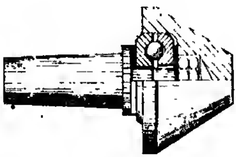


FIG. 82.—Rotating pipe-centre.

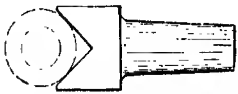


FIG. 83.—Vee-centre.

axis, so that holes can be drilled at right angles to the axis of the work, and faces milled parallel thereto.

They are chiefly used for work of circular section, the total angle of the vee ranging from 45° to 90° (Fig. 83). For the support of large work, the centre is provided with long arms, whilst, in certain small forms, the part carrying the vee is able to swivel on the body of the centre.

Centres are also used to form centre holes in work, and to start the holes for drills. For this kind of work there are several forms available. The one shown in Fig. 84, and known as the countersinking or centring centre, is the commonest. It is either

exactly a half centre or a little less than this. The latter form possesses the better cutting qualities.

The square centre (Fig. 85) is another form. The point of this centre is a square pyramid in place of the right cone of the ordinary centre. The edges of the pyramid act as the cutting edges. Their action is, however, more or less imperfect, since they act

Figs. 84 and 85. Centring and square centres.

with a very large amount of negative rake, a condition which is never associated with good cutting qualities.

A slight variation of this form is shown in Fig. 86. Each pyramidal surface is cut out or fluted to lessen the amount of work involved in resharpening the centre. The angle of the hole formed by this kind of centre is the angle between the opposite edges and not that between the opposite faces.

Figs. 86 and 87.—Fluted centres.

The fluted-point centre for centre drilling and countersinking is represented in Fig. 87. In this case the point of the centre has from 8 to 12 inclined, tapered flutes, these forming the same number of cutting edges. Unless the flutes are fairly deep —which is not usual, however—the cutting edges cannot be equipped with positive rake, and unless the point is specially ground—which, again, is not

usual—the cutting edges cannot be provided with any clearance or relief.

The square centre is also available as a driver of small-diameter work or work on which a very light cutting operation has to be performed. A pyramidal hole has to be formed in the end of the work by means of a punch before the centre can be used. In such a case the work can be machined from end to end without having to be reversed.

2. Driving or Catch Plates.

A driving or catch plate is used to drive work which is mounted between both centres of a lathe. It is usually screwed directly on or in the nose of the driving spindle, some part of the plate—either the back face of the boss or a shoulder in the bore—pressing against a collar or shoulder, which thus takes the cutting thrust. The thread of the screw is thus protected as much as is possible from the influence of the cutting forces.

The connexion between the work and the driving plate is a carrier or dog which transmits the driving power to the work by means of frictional resistance produced by the application of a pressure exerted through one or two screws. These press on the work either directly or through clamping plates. It is obvious that there is a limit to the size of carrier from the point of view of handling, and a limit to the power which such a form of driver is capable of transmitting. It is for these reasons that driving plates proper are very rarely made of a larger diameter than 14 inches, though improvised driving

plates of larger diameters are readily made from large face-plates.

There are, in general, two forms of driving plate: the pin plate, and the slotted plate. The former is used in conjunction with straight-tailed carriers, and carries one or two driving pins which project from its front face. The latter is used to drive carriers with bent tails, and contains one or two radial slots, in which the tails of the carriers fit.

A common form of pin plate, which is found on engine lathes, is shown in Fig. 88. In the plainest

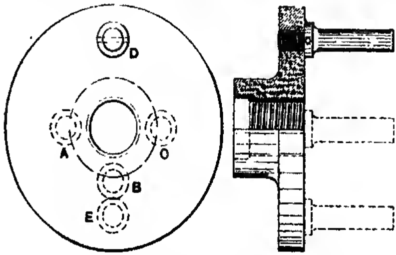


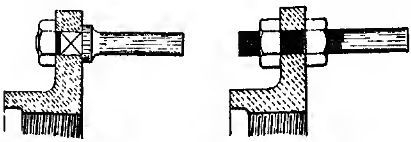
FIG. 88.—Pin driving plate.

form one pin only is used and this is held in a hole near the periphery of the plate. No other hole is provided, and the position of the pin is, therefore, non-adjustable. This condition is sometimes objectionable, especially when it is desired to use a small carrier on small-diameter work. In such a case it might not be possible to drive the small carrier, and a larger one would, thus, have to be used. To obviate such trouble a second hole can be provided nearer the centre of the plate, in any one of the positions A, B, C (Fig. 88). The pin can then

be moved from the one to the other as circumstances require.

There are several designs of pin in use in ordinary practice. The one shown in Fig. 88 is provided with a shoulder, which is screwed up against the face of the plate by means of a tommy wrench or bar fitting in a small diametral hole in a collar on the pin. A slight variation of this is the substitution of two parallel flats on the collar for the tommy hole.

Another form of pin is shown in Fig. 89. This is held in place by a nut at the back of the plate and, to prevent the rotation of the pin when the nut is being screwed on it, the pin has a square shank.



FIGS. 89 and 90.—Driving-plate pins.

Though the above are standard forms, they are defective inasmuch as the length of the projection of the pin from the face of the plate is invariable. The two forms represented in Figs. 90 and 91 do not possess this defect since, in each case, the position of the pin in the hole can be varied. In the first of these two forms the pin is secured by two nuts, one on each side of the plate. The screw thread extends a distance of about two-thirds of the total length of the pin. In the second form the pin is quite plain, and an easy fit in the plate. It is held in place by a grub screw, this mode of securing the pin admit-

ting of a very ready adjustment of position. A slight variation of this is in the elimination of the grub screw, and in the making of the fit of the pin in its hole a good driving fit, so that adjustments of position have to be made by striking the end of the pin with a hammer. This is, however, inferior to the other, since the repeated use of the hammer damages the end of the pin, and causes it to bulge out.

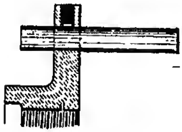


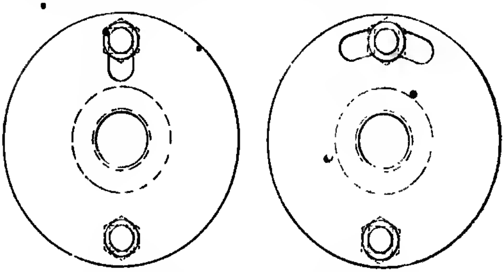
FIG. 91.—Driving-plate pin.

The single-point drive is not satisfactory for accurate or fairly heavy work, because during each revolution of the work there are two reversals of stress and deflection due to the cutting forces. This defect is eliminated by the use of the two-point, balanced drive. This drive is obtained by using two pins placed diametrically opposite to each other, as shown at A and C or D and E in Fig. 88. The use of such an arrangement of pins involves, of course, the use of a double-tailed carrier.

This plain diametral arrangement is, however, very rarely the exact arrangement which is required, owing to the fact that it is very difficult to arrange the work in the carrier so that both tails are disposed symmetrically with respect to the axis of the work. It is necessary, therefore, to adopt some method of adjusting the position of one of the pins for the purpose of making the drive a truly balanced one. The methods available are indicated in Figs. 92, 93, and 94.

In connexion with the first method, it is evident

that the adjustment is effected by moving one of the pins in a *radial* slot or elongated hole; whilst, in regard to the second method, a circular slot or elon-



FIGS. 92 and 93.—Slotted driving plates.

gated hole, concentric with the periphery of the plate, enables the adjustment to be made. It may be pointed out that the curved slot need not be

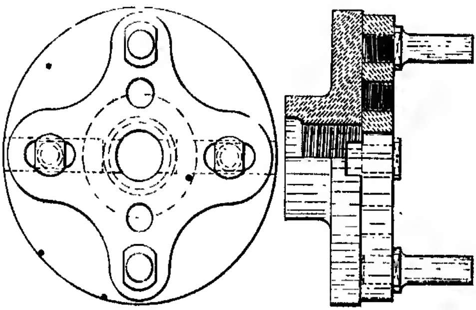


FIG. 94.—Clements' driver.

absolutely circular, nor concentric with the circle of the plate, though this is the most desirable condition. Of these two methods, the radial-slot method

is the better of the two, since the adjustable pin does not depend only upon frictional resistance, for its driving power, as it does in the other case.

The arrangement represented in Fig. 94 is known as a *Clements' driver*. The driver consists of two plates, one of which is mounted on the nose of the driving spindle, whilst the other carries the two driving pins, neither one of which is separately adjustable. The two plates are held together by two bolts, studs, or screws, but the fitting of these is such that, whilst the front plate cannot fall away from the other, it can move tolerably easily on its face. The screws are held rigidly in the back plate. Their holes in the front plate are elongated, as shown, to allow for lateral movements of this plate. The line joining the centres of the two screws is exactly at right angles to the line which joins the centres of the two driving pins. In the older forms of this driver, the driving force was transmitted through the studs or screws holding the two plates together, these screws thus being in shear. In the modern forms a diametral tongue of rectangular section is placed on the back of the front plate and parallel with the line joining the centres of the two screws, this tongue fitting in a corresponding groove or slot in the front face of the back plate. This tongue acts as the transmitter of the driving force, and thus relieves the screws of practically all stress. Two sets of driving-pin holes are sometimes provided, as shown in the figure.

The action of this driver is purely automatic, no hand-adjustment of any kind being required. If, at any time, only one pin is driving the work, this will

be reacted upon by the resistance exerted by the work, and constrained to move with the whole of the front plate so that the other pin and carrier tail get into driving contact. This dual contact is then maintained provided that the working conditions remain fairly constant.

The ordinary slotted driving plate is represented in Fig. 95. The slot is a radial one which usually runs down almost to the boss of the plate. It is, therefore, possible to use several sizes of carriers on

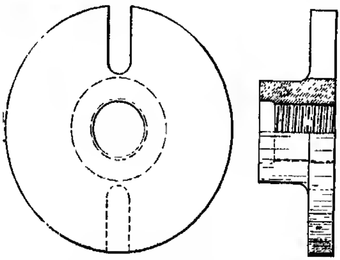


FIG. 95.—Slot driving plate.

a plate of this description without having to make any change whatsoever.

Two radial slots opposite each other are sometimes provided. They are very rarely used in conjunction with double-tailed carriers for two reasons: first, very few double carriers with bent tails are in existence; and, second, it is almost impossible to get a balanced drive under ordinary working conditions with a bent-tailed carrier. The slots are, however, frequently used to carry driving pins, in which case, of course, it is possible to get a balanced drive.

In Fig. 96 is shown a form of driver which is

used on hand-turning and brass-finishing lathes. It is not exactly a plate, but a body which carries the

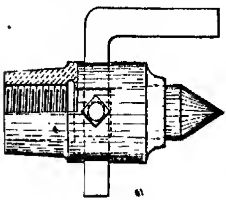


FIG. 96.—Centre driver.

centre and is screwed on the nose of the driving spindle. The actual driving element consists of a bent bar—which acts as a driving pin,—the position of this in the body being adjustable, so as to allow for different sizes of carrier. The bar is held in place by a set screw.

In this case the running truth of the centre depends chiefly upon the running truth of the body, and the latter depends almost entirely upon the fit of the body on the nose of the spindle.

When this form of driver is used on internally threaded spindle noses, the centre is formed on the body, and is thus solid with it. In such cases the centre points may be either fluted or smooth.

A centre driver is represented in Fig. 97. A driving pin of rectangular section is inserted in a milled slot in the shank of the centre, and held in position by a small grub screw. The end of the pin is approximately coincident with the point of the centre, and it fits in a groove in the end of the work. As a driver for small-diameter work or work on which very light cutting operations have to be performed, this form is superior to the square centre, since the drive is a more positive one, and less likely to fail if the duty imposed upon it is increased.

A driving element which forms a variation to the

pins illustrated in Figs. 88-91 is indicated in Fig. 98. It replaces the plain pin when it is necessary for precision purposes to connect the carrier rigidly to the driving plate. The design of the element is that of a fork, in which two opposite sets of set-screws are situated. The tail of the carrier required in

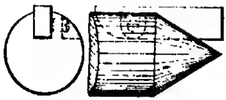


Fig. 97.—Centre driver.

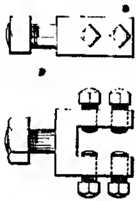


Fig. 98.—Driving dog.

such a case is flat, and this is pinched between the two sets of screws. The element is, of course, located in the hole or slot in the driving plate, as is the plain form of pin.

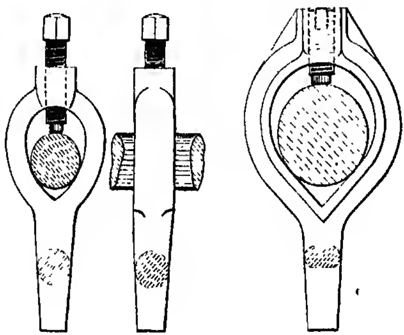
3. Carriers or Dogs.

A lathe carrier or dog is the connecting element between the driving plate and the work. It is used, in one form or another, in the majority of cases where the work is supported on the two centres. Practically the only exceptions occur when a centre form of driver is employed.

Lathe carriers or dogs can be classified in three different ways: first, in regard to the method of securing the carrier on the work; second, in regard to the number of driving tails; and, third, in regard to the form of the tails.

The first classification differentiates between the screw carrier and the clamp carrier; the second between the single-tailed and the double-tailed carrier; and the third between the carrier with bent tails and the one with straight tails.

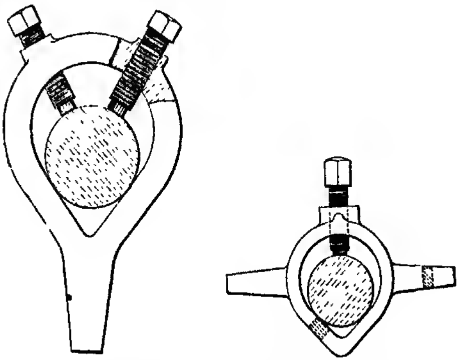
The ordinary form of straight-tailed screw carrier is represented in Fig. 99. The frictional resistance —which really constitutes the driving force to the work—is exerted at three points, two being on the



FIGS. 99 and 100.—Screw carriers.

carrier and one on the end of the screw. The screw is fitted in the head of the carrier, and is screwed down directly on to the work. It may be either a headed or a headless screw, the latter of these two forms being preferable, since it does not project beyond the head of the carrier and prove an element of danger to the operator of the machine. Headed screws may have either square (Fig. 99) or hexagonal heads, these being tightened up by means of spanners, wrenches, or box-keys, or round heads, with

tommy-wrench holes (Fig. 103). The headless form of screw (Fig. 100) has either a blind square or hexagonal hole in it, and to tighten this up a correspondingly shaped plug key is required. The point of the screw should, preferably, be reduced in diameter, as shown, and hardened. This prevents the end from being upset by the repeated pressure-applications. The section of the body and tail is either circular (Fig. 99), a flattened oval (Fig. 100)



FIGS. 101 and 102.—Screw carriers.

square, or rectangular (Fig. 102), the second and fourth being slightly superior to the others, since, weight for weight, they are much stronger. In the case of the second a flange (Fig. 100) is sometimes formed on the inside of the body.

In Fig. 101 is represented a two-screw or four-point carrier. It is stronger and has greater gripping power than the single-screw form. The screw axes are disposed at an angle of from 60° to 90° with respect to each other.

The tail of a carrier is ordinarily immediately opposite the head, but in one or two rather exceptional cases this condition does not hold. In one form—described as a safety carrier—the tail is bent round so as to cover the head of the screw, and the drive is then at the screw end of the carrier. The object of bending the tail round is to cover the projecting screw head and reduce the risk of danger; this object can, however, be realized quite as effec-

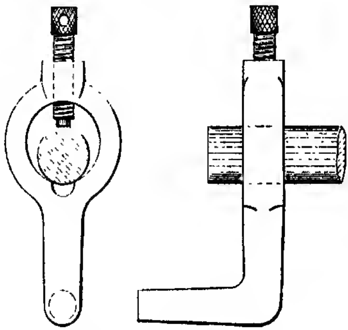


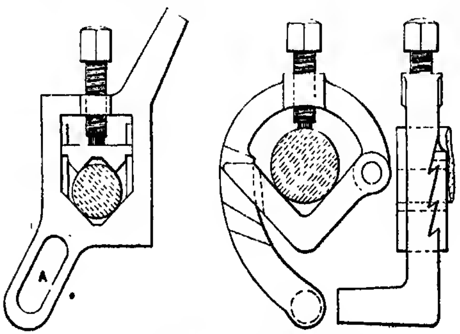
FIG. 103.—Bent-tailed screw carrier.

tively by the use of a headless screw. In the case of the double-tailed carrier, however, it is necessary to dispose the tails in positions other than that which is immediately opposite the head. The commonest arrangement is indicated in Fig. 102, the two tails being opposite one another with respect to the body of the carrier, but not necessarily exactly so with respect to the work held in the carrier.

The ordinary form of bent-tailed carrier is represented in Fig. 103. This carrier is usually a solid

steel forging—as all carriers should be—though, in one or two cases of light carriers, the tail is either screwed or riveted in the body. Carriers with two bent tails are very rarely used.

The three-point drive is obtained, as shown, by utilizing the edges formed by the intersection of the large circular hole in the body and a much smaller one at the bottom. The usual shapes of the body hole are indicated in Figs. 99 to 102.



Figs. 104 and 105.—Screw carriers.

A special form of straight-tailed screw carrier is shown in Fig. 104. Although it possesses only one screw, the drive is a four-point drive, this being obtained by the use of a shaped sliding die which is pressed directly on the work by means of the screw. The die may work in guides, as shown, and be separate from the screw, or it may be attached to the screw by a small grub screw, fitting in an annular groove in the end of the holding-in screw.

This form of carrier is useful in cases where it is

desired to connect the driving plate positively to the carrier. This can be done by inserting the pin in the slot, A, in the additional tail. The other tail is for an ordinary drive.

Screw carriers are also made of the adjustable type. One form of such is indicated in Fig. 105. In this case the body is open. From one end the tail projects, whilst at the other a swinging arm is hinged. The free end of this arm can be placed in any one of a number of vee'd grooves in the face of the body, and lodged therein, the work being held securely between this arm and the end of the holding-in screw.

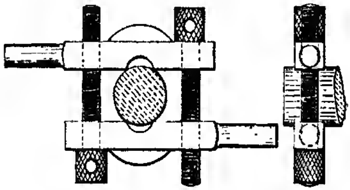


FIG. 106.—Clamp carrier.

In another form the tail is loose and capable of being fitted on any of a number of pairs of notches on the body, so that adjustments are effected by moving the tail. All carriers of this type are, however, defective, inasmuch as they have a number of uncovered projecting parts.

Clamp or plate carriers are, generally, much stronger than screw carriers, though they are usually much larger and used, therefore, in connexion with heavier work. They are of both the single- and double-tailed forms, but the latter form is by far the one more commonly employed. Also, both bent and

straight tails are used on them, of these the latter being considerably more used than the other.

A light form of clamp carrier is represented in Fig. 106. The drive in this case is a four-point drive—this being characteristic of clamp carriers,—the four points being provided by the edges of two curved grooves in the clamp plates. In place of the curved grooves, vee-grooves are frequently found, whilst in some cases the grooves are dispensed with entirely, and the plates are shaped to fit the contour of the work. The two plates are drawn towards each other by means of two set-screws (with either round, square, or hexagonal heads), which point in opposite directions, and are screwed into the opposite plates and clear in those on which their heads bear. In this case the tails are extensions of the plates, either solid with them or screwed into them.

A stronger form of clamp carrier is indicated in Fig. 107. The two plates are drawn towards each other by means of two bolts and nuts, and the tails project from the middle parts of the two plates. The combined plates and tails are solid steel forgings.

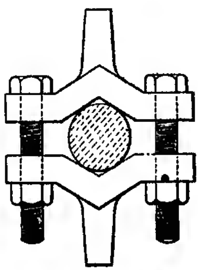


Fig. 107.—Clamp carrier.

Another form consists of a right-angle bar with a longitudinal slot in each of the two arms. A strap bolt is used, the two ends of this passing through the slots in the bar. Nuts and washers placed on these ends complete the equipment. The work is gripped

in the space between the bar and the bolt, a four-point drive resulting. In another form, a U-bolt in the body of the carrier draws up a sliding die, between which and a vee in the body the work is secured.

All the above forms are more suitable for the holding of parallel work than that of tapered work, though, where the degree of taper is slight, there is not, usually, any real objection to the use of any of them. A form of carrier which is, however, equally serviceable in the two cases is represented in Fig. 108.

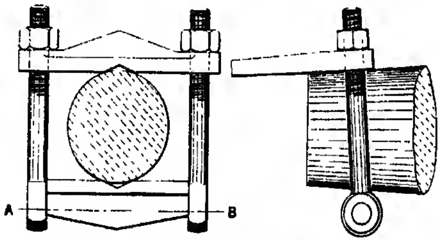


Fig. 108.—Clamp carrier for tapered work.

The bolts which are used in this case are eye-bolts and are hinged about the axis of the lower plate at A and B. It is thus possible for the two plates to occupy positions which are inclined to one another, and, to change these positions more or less automatically.

In Fig. 109 is shown a form of carrier which is suitable for the gripping and driving of threaded or screwed pieces of work. The usual method of fitting a piece of brass tube round the threaded part and using an ordinary screw or clamp carrier is an execrable one, and in up-to-date works should not be

tolerated. The method illustrated here is vastly superior. The carrier, which may be either straight or bent-tailed, is provided with a split head, through which passes a closing-in set-screw. The body of the carrier is circular, and carries a circular hole, in which any one of a number of split threaded dies may be inserted, and prevented from rotating therein by a grub-screw, A, the inner end of which enters a longitudinal slot in the side of the die. The operation of closing the body in on the die also causes the die to be closed in on the work. A carrier of this form must, of course, be equipped with dies of different thread diameters and pitches, if its use is to be fairly extensive.

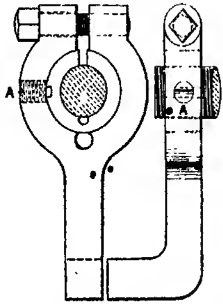


FIG. 109.—Dog for threaded work.

4. MANDRELS.

When work which is hollow has to be driven in a lathe so that practically every part of its exterior is accessible to the cutting tool, it is necessary to mount it on an element which is known as a mandrel. Usually the mandrel has to be placed between the two centres and driven by a carrier from the driving plate, but a mandrel may also be used to carry work when driven directly from the driving spindle or from a chuck.

Mandrels are also used on other machine tools,

such as milling machines, shapers, slotters, etc., but their distinguishing characteristic is found in the fact that they carry *work pieces*.

There is, however, some little confusion here. Mandrels are often referred to as arbors, but such a description is not quite correct, there being a well-defined distinction between these two machine-tool elements. An *arbor* carries rotating *cutting tools* in almost precisely the same manner as a *mandrel* carries *work pieces*, and it is not correct to use the two descriptions interchangeably.

The simplest form of mandrel is a piece of wood turned very slightly taper, on which the work is forced. Accurate work cannot, however, be done by such means; hence mandrels are made almost universally of metal, and chiefly of iron and steel.

Metal mandrels may be divided into the following classes: solid mandrels; self-tightening mandrels; adjustable or expanding mandrels; nut or threaded mandrels; and special mandrels.

The solid mandrel is a plain bar of circular section. It is slightly tapered from end to end, the degree of taper amounting to about 0·01 inch per foot length of mandrel, measured on the diameter. It exists in two forms: the unhardened and the hardened forms. The former is usually an improvised mandrel, but it should very rarely be used. Its condition, it is true, lends itself easily to a change in diameter, though where there is a slight variation in the diameters of the holes of work pieces, it is far better to employ some form of expanding or adjustable mandrel. The latter is usually a standard mandrel, and as such is made of high-carbon crucible steel, hardened, and ground

accurately to size, whereas the unhardened mandrel —which may be made of a cheap grade of iron or mild steel—is sometimes never even finish-turned.

A standard mandrel is made of a standard nominal diameter, so that it can be used in conjunction with standard holes. The diameter at one end is less than, and the other greater than, the nominal diameter, this latter occurring near the middle point in the length of the mandrel.

The two ends of a solid mandrel—and the two ends of the bodies of many other forms of mandrel—should be reduced in diameter below that of the bearing part,

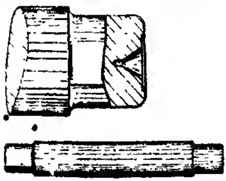


FIG. 110.—Standard mandrel.

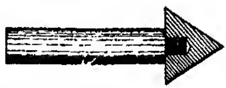


FIG. 111.—Lap.

and each should have a flat machined on it (as shown in Fig. 110) to take the thrust of the carrier screw. A centre hole is carried in each end, the axes of the two holes being coincident with one another and with the axis of the mandrel. These holes usually have an included angle of 60°, this angle running into a small, parallel pilot hole, which carries lubricant and protects the extreme point of the centre. The mouth of the centre is either chamfered or curved slightly, or the end of the mandrel is slightly recessed, the object of this being the protection of the centre hole, as any damage to the surface of this would lead to the

production of inaccurate work. If, in spite of this precaution, the centre hole is damaged in any way, it should be lapped out carefully. One form of lap which is suitable is shown in Fig. 111. It consists of a lead or copper conical head screwed on a steel shank. The total angle of the cone must, of course, be equal to the total angle of the centre-hole. By means of this tool and a lapping compound (such as finely sifted high-grade emery and oil) any unevenness of the surface of the centre-hole can be removed.

A solid collar mandrel, which is used to carry work having a large hole, is indicated in Fig. 112; whilst,

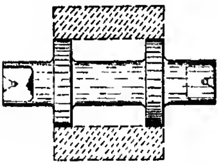


FIG. 112.—Collar mandrel.

FIG. 113.—Stepped mandrel.

in Fig. 113, is shown a solid stepped mandrel, which is available for a number of diameters of hole, provided that the work pieces are comparatively narrow.

Two forms of self-tightening mandrel are represented in Figs. 114 and 115. In each case the fit between the body of the mandrel and the work is a close push fit, whereas that which occurs in the case of the solid standard mandrel is always a driving fit. A longitudinal pin fitting in a vee-groove in the surface of the body is used in the case illustrated in Fig. 114. When any slight movement of the work relative to the mandrel occurs, the pin is caused to move and wedge itself in the space between the work

and the mandrel. In the other case, any relative movement between the two chief elements causes a segmental insert to wedge itself in between them.

Self-tightening mandrels are, however, open to the

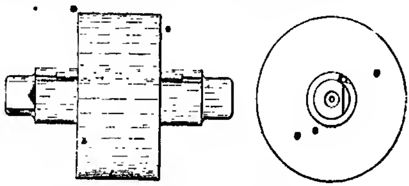


FIG. 114.—Self-tightening mandrel.

objection that, if the fit between the hole and the body is not a close one, the action of the wedge causes the axes of the work and mandrel to become non-coincident, and the work, therefore, to be turned eccentric.

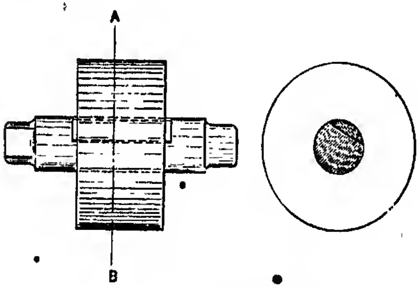


FIG. 115.—Self-tightening mandrel.

Adjustable or expanding mandrels are many and various. Their chief province is in the carrying of work pieces which have holes of slightly varying diameters. In cases where the exact diameter

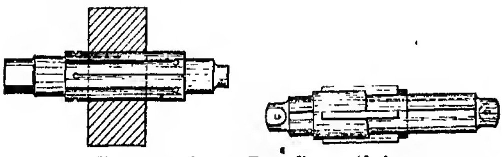
of the hole is of no material importance, their work is quite legitimate, but as substitutes for solid mandrels they have no place.

In Fig. 116 is shown a simple form of expanding mandrel. It consists of a tapered body which carries a closely coiled spring. The spring is tapered internally but parallel externally, and any

FIGS. 116 and 117.—Expanding mandrels.

longitudinal movement causes it to expand or contract on the body.

Another simple form is indicated in Fig. 117. In this case a split sleeve fits on a tapered body, and longitudinal movements cause the sleeve to open or close, that is, to expand or contract. The sleeve is split from the outer surface to the hole in one plane,



FIGS. 118 and 119.—Expanding mandrels.

and about half-way through in two other planes each disposed at 120° to the first. An elaboration of this principle is indicated in Fig. 118. The sleeve in this case is split longitudinally in several places, but not quite from end to end as in the former case. The slits are arranged alternately from each end and terminate in small holes. Such a sleeve, when properly hardened, is highly elastic.

The Nicholson expanding mandrel is represented in Figs. 119 and 120. This mandrel consists of a grooved body, with four sliding jaws fitting in the grooves, which are slightly tapered at the bottom. These jaws are held in the grooves by a loosely fitting sleeve which, as it is moved on the parallel body,

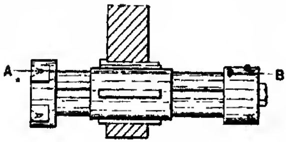
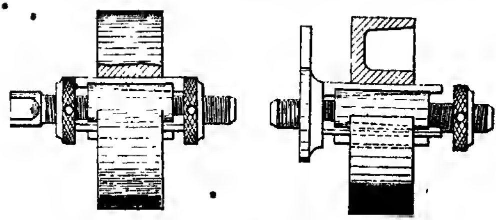


FIG. 120.—Nicholson eccentric mandrel.

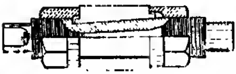
carries the jaws with it and causes their outer faces to move towards or away from the axis of the mandrel. Its actual diameter is thus altered slightly. In Fig 120 is shown the case of a mandrel of

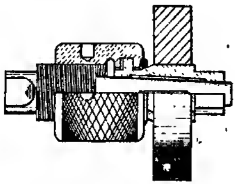


FIGS. 121 and 122.—Expanding mandrels.

this form—adapted for the carrying of eccentric work. Special ends are provided, and these are arranged with two sets of centre-holes, the distance between the axis of one of the sets and the axis of the mandrel being equal to the eccentricity required. In the figure, AB represents the axis of rotation and the axis of the external circumference of the work.

The mandrel shown in Fig. 121 consists of a threaded shank, on which a body with three evenly spaced tapered grooves is mounted. In the grooves fit three sliding jaws, which are moved longitudinally by means of two nuts. An improved form is that shown in Fig. 122. In this case part of the mandrel acts as the driver, and the application of the driving force tends to increase the grip of the mandrel in the work. A somewhat similar form is shown in Fig. 123, but in this case the grooves are formed in the threaded shank, and the nuts are recessed to prevent the jaws from dropping out of



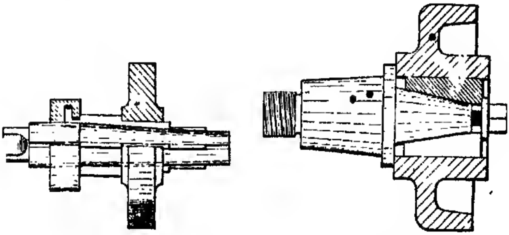


FIGS. 123 and 124.—Expanding mandrels.

the grooves. A still more elaborate design is represented in Fig. 124. In this design the jaws are moved on a tapered body by a long recessed nut, the jaws being prevented from rotating with the nut by wards which fit in grooves in the undersides of the jaws. A spring keeps the jaws on the body. The jaws are stepped, two nominal diameters being thus allowed for. In another form shown in Fig. 125, the jaws, which are three-stepped, are fitted in inclined grooves in the body, and moved along in them by means of a recessed head.

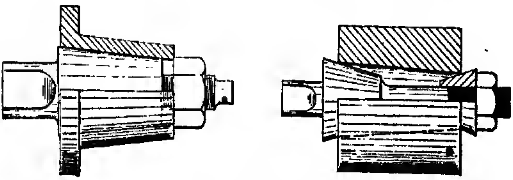
The expanding mandrel indicated in Fig. 126 is

secured in the tapered socket of the driving spindle of an engine or turret lathe. The expansion of the split mandrel sleeve is effected by screwing up the set-screw, in place of which a stud and nut would serve equally well.



FIGS. 125 and 126.—Expanding mandrels.

A mandrel for carrying a tapered or conical work-piece, such as a bearing bush, is shown in Fig. 127. In this case the taper of the mandrel must coincide with that of the interior of the work. Another method of mounting a work-piece with a tapered

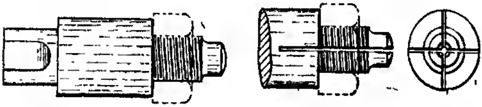


FIGS. 127 and 128.—Mandrels for tapered work.

hole is indicated in Fig. 128. This method can also be used for work-pieces with parallel holes of varying diameters.

The nut drive is also shown in Fig. 198, which represents an automatic lathe operation.

A mandrel for carrying nuts which have to be faced is represented in Fig. 129. One end is threaded to take the nut, whilst the other is arranged with a flat for the carrier screw. This form can be slightly altered to fit it for use in a chuck instead of between centres. A slight improvement in the design of the threaded end is indicated in Fig. 130. This end is split orthogonally, and the fit of the thread made rather slack. The action of forcing the centre in the centre hole causes the four parts to open out slightly and grip the nut. For rough or black nuts with uneven faces the mandrel shown in Fig. 131 is suitable. It is



FIGS. 129 and 130.—Nut mandrels.

provided with a washer on a spherical seat, this washer automatically accommodating itself to any irregularity of surface. This prevents the nut from being faced at an angle to its axis, a condition which obtains with an ordinary nut mandrel in such a case when the fit between the screw and the nut is not a good one.

Fig. 132 represents a form of mandrel which is suitable for the machining of concentric piston-rings. It is mounted directly on the nose of the driving spindle, and consists of a stepped body and gripping sleeve, the ring being secured, as shown, by tightening up the nut.

5. FACE-PLATES AND ANGLE-PLATES.

Face-plates are distinct from driving or catch plates, inasmuch as they are used to carry work-pieces bolted to them, either directly or indirectly, or to carry dog chucks or jaws (in the case of large lathes only) which grip the work. They are mounted on the threaded nose of the driving spindle in the case of small and medium-sized lathes, and attached to a flange on the end of the spindle in the case of lathes having centre-heights greater than 13 or 14 inches.

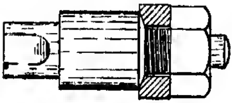


FIG. 131.—Nut mandrel.

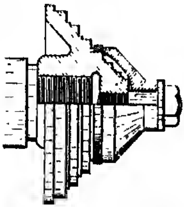


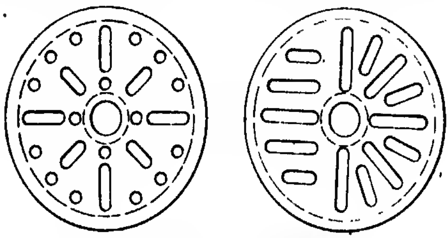
FIG. 132.—Piston-ring mandrel.

They are circular in form, and are of two distinct types: the small type, which carries holes and slots which pass right through the plate; and the large type, which contains tee-slots in its front face, the back being quite solid. Plates of the former type are very rarely made of a larger diameter than 27 inches, whilst plates of the other type usually have diameters which are greater than 24 inches.

The dispositions of the holes and slots in the small type of plate are many and various. The slots may be either radial or parallel, and either long or short, whilst the holes may be round or square. Three

common arrangements are indicated in Figs. 133 to 135. The first is suitable for general work; the second for general and angle plate work; and the third chiefly for angle-plate work. The clamping bolts are, of course, placed in the holes or slots.

The tee-slots of the larger face-plates are also disposed in several ways. They may be either radial or parallel, and either long or short. Parallel slots are, however, necessary when dog chucks or jaws have to be carried, tongues or wards on the back faces of these fitting in the necks of the slots. In all



FIGS. 133 and 134.—Face-plates.

cases, the tee-heads of the bolts should have a good fit in the slots, so as to make the hold as rigid as possible.

Face-plates above, say, 12 inches in diameter should be provided with circular flanges and radial ribs for strengthening purposes. If this is done, the whole weight can be reduced without producing weakness.

Large face-plates which are secured to the flange on the end of the headstock spindle are usually gear-driven, a spur or helical pinion meshing with a spur or helical wheel secured to the face-plate. The wheel

on the plate may be either an external or an internal one, and it may be secured to the plate by means of bolts or screws, or be solid with it.

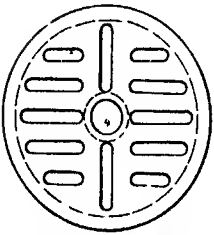


FIG. 135.—Face-plate.

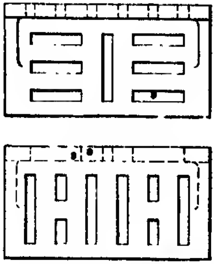
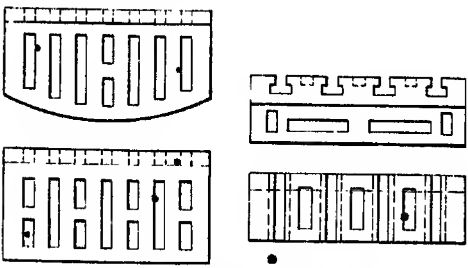


FIG. 136.—Angle-plate.

Angle plates are used to carry work which cannot be satisfactorily carried directly on face-plates. These plates, which are usually right-angle plates,



FIGS. 137 and 138.—Angle-plates.

are bolted to the face-plates. Four different designs are shown in Figs. 136 to 139. The first two are the ordinary forms met with, the curvature on the second being made to suit the circumference of the

face-plate. The third form is more solid and used in conjunction with tee-headed bolts. The fourth is a vee angle-plate, and is useful in connexion with the driving of work of irregular form, which has to be bored or otherwise internally machined.

6. Chucks.

A chuck is a revolving vise, in or on which the work is held by friction resistance, this resistance being caused by pressure exerted on the work through adjustable elements which are permitted to move radially only. These elements may be screws, sliding jaws, or the several parts of split bushes, but they all possess the characteristic radial adjustment.

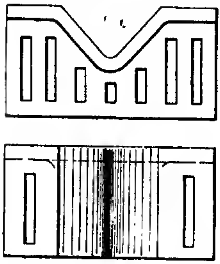


Fig. 139.—Angle-plate.

Lathe chucks may be divided into three principal classes as follows:—

(*a*) Self-centring or concentric chucks;
(*b*) Independent-jaw chucks; and
(*c*) Combination chucks.

The first class comprises all chucks in which all the holding elements or jaws move simultaneously towards or away from the centre; the second class includes all chucks in which there is no connexion whatever between the adjusting mechanisms of the several jaws, so that any one jaw may be moved without affecting in any way the positions of the

others; whilst the third class contains those chucks of special design which can be used as either self-centring or independent-jaw chucks, as desired—hence the description combination chucks.

So-called universal lathe chucks are of the self-centring type. They carry either three or four jaws which slide in radial grooves in the front face of the body of the chuck. The movements of the jaws are controlled in at least four different ways. The first is by square-threaded screws; the second by a projected scroll; the third by a projected spiral; and the fourth by cams.

A four-jaw screw chuck is represented in Fig. 140. Each jaw has a back projection which fits inside the body of the chuck, this projection having a threaded radial hole, through which passes a screw. This screw has bearings in the body, so that no longitudinal or radial movement of it is possible. Hence any rotation of the screw produces a radial movement of the nut and the jaw to which it is attached. The four jaw-screws are connected by a large bevel wheel or circular rack which, reposing in an annular groove in the body, is in mesh with bevel pinions on the screws. The body is split about the axes of the screws, so that the screws can be inserted in the body, the two parts being held together by set-screws. Each jaw-screw has a square

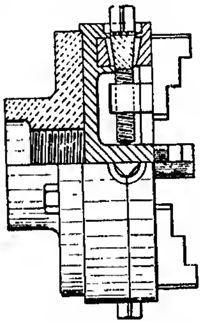


FIG. 140.—Screw chuck.

outer end, a chuck- or box-key being used on this to rotate the screws and move the jaws. A cast-iron back plate is attached to the body of the chuck for the purpose of connecting it to the nose of the driving spindle. The various parts of the chuck are made of steel, several of them of steel forgings, and some hardened.

The distinguishing element of the scroll chuck, one form of which is represented in Fig. 141, is the

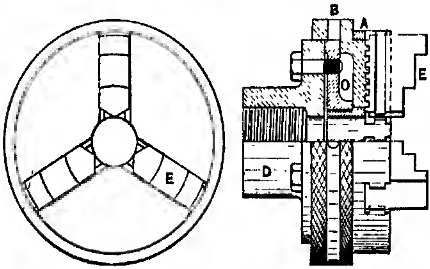


FIG. 141.—Scroll chuck.

scroll. In this form the body, A, contains a plate, B, on the front face of which is formed a projected scroll of square section, the shape of the scroll being that of an Archimedian spiral. This plate is rotated with respect to the body in which the jaws, E, fit. On the back of each jaw are curved projections which correspond to, and fit in, the spaces of the scroll. Since the basic principle of the Archimedian spiral is that of constant or uniform recession or approach with respect to a central point, it follows that any rotation of the scroll with respect to the body and jaws will cause the jaws to move radially and equally. A point to notice here is that the radius of curvature

of the spiral is a constantly varying quantity, so that the "fit" between the jaws and the scroll is more or less variable. The degree of variation is, however, in new chucks very slight, and for each of the jaws practically the same. The scroll plate, B, is held in the body by a plate, C, and rotated by means of a tommy or pin wrench working in one of the tommy holes shown. D is the chuck plate or adapter.

Another, and more common form, is indicated in Fig. 142. In this case, the scroll plate is fitted at the back as a circular rack, in mesh with which are three or four bevel pinions, so that the scroll is rotated by turning any one of these pinions. Each pinion is provided with a blind square hole, in which a plug key is placed to turn it. This obviates the necessity of having projecting square ends. The pinions and rack are held in place by a back plate, to which the threaded chuck plate is attached.

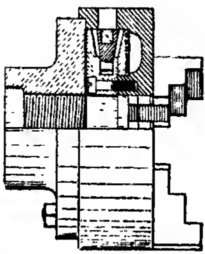


FIG. 142.—Scroll chuck.

The spiral chuck, as made by Messrs. C. Taylor, Ltd., of Birmingham, is a decided advance upon the original scroll chuck. In this case the projected spiral—which is also Archimedian in character—is formed on an internal conical surface, as shown in Fig. 143, with a total angle of 120°, the section of the scroll being triangular, with an included angle of 60° and one edge parallel to the axis. Fig. 144 shows the back of the spiral plate, and the arrangement of

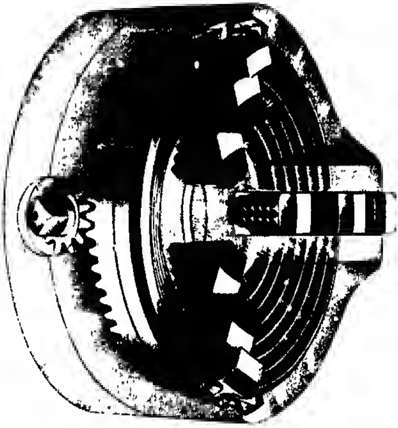


Fig. 143.—Interior of spiral chuck.

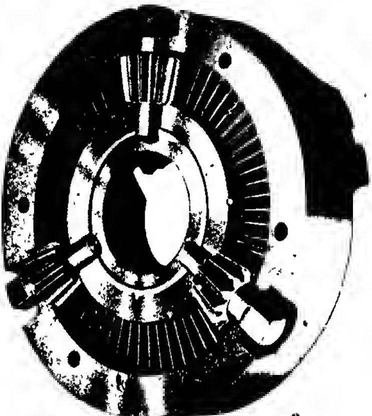


Fig. 144.—Spiral-chuck rack and pinions.

the gearing. Fig. 145 represents one form of this chuck, suitable for small-diameter bar work, whilst the form shown in Fig. 146 is more suitable for large-diameter work of no great length.

A recent form of worm-actuated cam chuck of the concentric type is indicated in Fig. 147. The jaws, which are three in number, have back projections or

FIG. 145.—Spiral chuck.

spigots which fit in eccentric slots in a cam plate in the body of the chuck. The cam plate is rotated by means of a worm in the body and a worm-wheel which is formed on the periphery of the plate. Any rotatory movement of the plate produces equal and simultaneous radial movements of the three jaws.

Two-jawed chucks are frequently of the self-cent-

ring type. Fig. 148 represents one form of many.

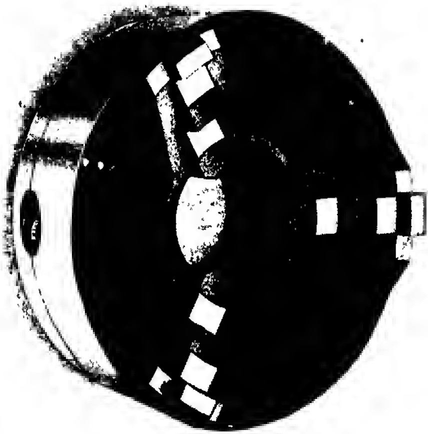


FIG. 146.—Spiral chuck.

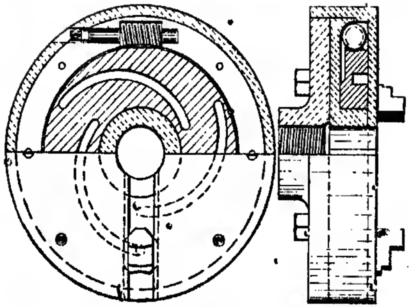


FIG. 147.—Cam chuck.

A screw with two threads of different hands is

employed, these meshing with threads on the sides of the two jaws, which slide in radial slots. Hence, any rotation which may be given to the screw produces equal, opposite, and simultaneous radial movements of the jaws.

Concentric chucks of the split-sleeve type are largely used in turret lathes and automatic machines for gripping bars. They are also used in hollow-spindle engine lathes, especially of the tool-room variety. The methods of closing them up on the bars are several. Those which are used on the former machines are semi-automatic or full-automa-

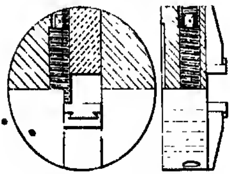


FIG. 148.—Two-jaw chuck.

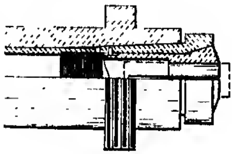


FIG. 149.—Split chuck.

tic, the principle of the inclined plane being generally used, whilst on the latter machines the movements are made by hand. Fig. 149 shows a hand-actuated split-sleeve chuck. It consists of a sleeve or collet, split for three-quarters of its length in three or four planes uniformly disposed with respect to each other, and fitting in a seating formed in the end of the driving spindle or in a connecting bush. The ends of the seating and collet are correspondingly tapered, so that, when the collet is drawn into the seating, it is caused to contract slightly and close upon the work. The drawing-in is accomplished by

means of a threaded tube which, passing through the spindle, is screwed on the inner end of the collet. A turn of the hand-wheel attached to this tube draws the collet in. A key fixed in the seating prevents the collet from rotating with the draw-in tube. In some cases the seating bush is socketed in the spindle; in others, it is screwed on the nose of the spindle.

The turret-lathe form of split chuck is usually arranged so that the collet is forced outwards against

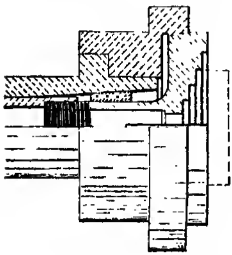


FIG. 150.—Split chuck.

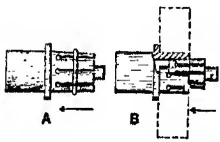


FIG. 151.—Wood chucks.

the tapered nose of a cap; whilst in some forms of drill chuck which contain split collets, a taper ended cap is screwed on the body to hold the collet in place on the work.

An internal-stepped split chuck is shown in Fig. 150. Its principle of action is similar to that of the above.

The collets of split chucks—especially of the automatic type—are frequently made in two or three parts, these being formed by carrying the slits from end to end of the collets.

Two forms of split wood chucks are shown in Fig.

151. For occasional work, in connexion with which no great degree of accuracy is required, they are suitable. They have, however, to be carried in universal jaw chucks, or socketed in the spindle and are, probably, more of the nature of mandrels than chucks. Each consists of a sleeve whose outer end is split uniformly. The periphery of the end of the A form is slightly tapered, and on this fits a ring, which causes the jaws of the chuck to contract on the work when it is forced on in the direction of the

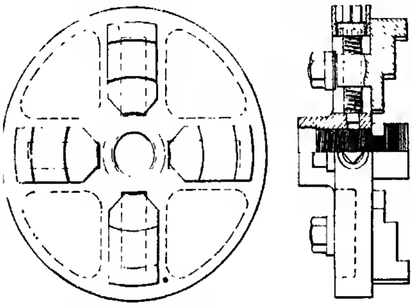


FIG. 152.—Independent-jaw chuck.

arrow. It is the interior of form B which is tapered, and in this fits another correspondingly tapered sleeve, which carries the work. When the plug sleeve is moved in the direction of the arrow, it is caused to contract on the work. This latter form can be used also as a mandrel for hollow work, as indicated by the dotted lines.

Independent-jaw chucks work almost universally on the screw principle, the movements of each jaw being controlled by a separate screw. A common

form of such a chuck is illustrated in Fig. 152. In this form each jaw is fixed in the chuck body by a nut at the back, and this nut has to be released slightly before the adjusting screw can be used.

Fig. 153 illustrates the application of the same principle to the case of a two-jaw chuck. This form is commonly known as a "box chuck".

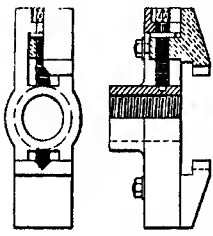


FIG. 153.—Box chuck.

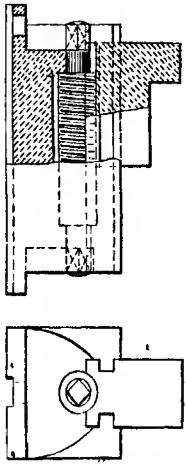


FIG. 154.—Dog-chuck jaw.

Dog chucks, which are built up on face-plates, are of the independent-jaw type. In this case, however, the jaws are usually placed in bodies which can be moved on the plate and removed when necessary. Face-plates to carry such bodies must have parallel slots. Two arrangements of jaws are indicated in Figs. 154 and 155. In the former case, the back of the jaw acts

as the nut; in the latter, a special nut and guiding plate are provided. A form of screw-dog which is much used on small face-plates is shown in Fig. 156. It is held in a hole of the face-plate by a nut at the back. The screw is used as a jaw to exert pressure on the work when used in conjunction with two or three others.

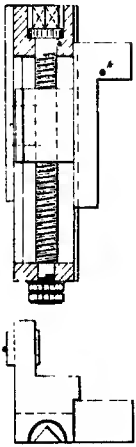


FIG. 155.—Dog-chuck jaw.

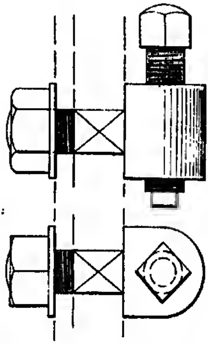


FIG. 156.—Screw-dog.

Boring and turning-mill chucks are either of the independent-jaw or dog-jaw type.

Screws are also used in the bell or cup chuck, which is shown in Fig. 157. In this chuck either 4, 6, or 8 radial screws may be used, these lying in two planes at right angles to the axis of the chuck. Though old in design, this type of driver is still unsurpassed for certain kinds of work, such as short

work of a more or less irregular shape on the end of which a facing or boring operation has to be performed.

The jaws of both scroll and screw-controlled chucks are made to hold, externally, work of small or large diameter and, internally, work having medium-sized and comparatively large holes. It is not possible, however, to perform all these with one set of jaws fitted in the chuck in one way; therefore it is necessary to have the jaws reversible or to have an additional set. Scroll-chuck jaws are very rarely completely reversible—there is only one known

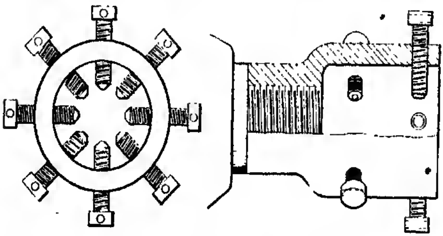


FIG. 157.—Bell or cup chuck.

case of such—owing to the fact that reversal of the threads on the backs of the jaws accompanies reversal of the jaws. The jaws of screw chucks are, however, usually reversible. To obviate the necessity of having to remove the jaw-bodies entirely, false jaws are sometimes used. These are the stopped parts of the jaws, and are attached to the sliding bodies. There are several arrangements in use; one is shown in Fig. 158. This method is also applicable in the case of scroll-chuck jaws. Another screw-chuck jaw device for the same purpose is shown in Fig. 159.

Slip jaws are frequently used on two-jaw chucks

(Fig. 148) for brass work, the slips being of various shapes to suit different kinds of work. The use of such slips extends the sphere of usefulness of a chuck.

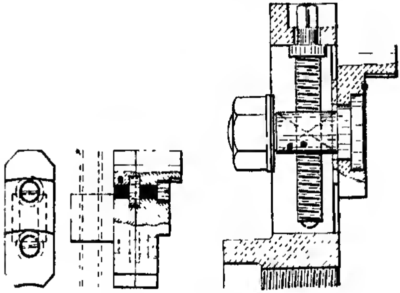


Fig. 158 and 159.—Chuck jaws.

The combination chuck is of two forms. In one form, which is represented in Fig. 160, the jaws are in two parts, these being connected together by radial

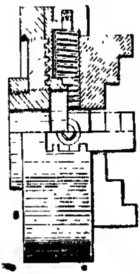


Fig. 160.—Combination chuck.

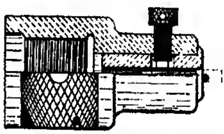


Fig. 161.—Wire chuck.

screws. The back parts have their movements controlled by a scroll, which is actuated by hand from the back or through bevel or spur gearing in the chuck.

These constitute the self-centring element. The front parts form the independent element. In the other form, the chuck is of the screw type, the circular rack which connects the bevel pinions on the screws being capable of moving out of engagement. This movement is usually obtained from a knob on the body of the chuck.

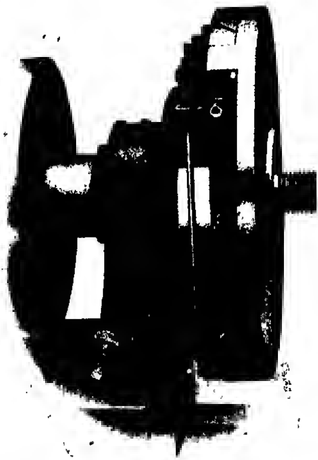


Fig. 162.—Oval or elliptical chuck.

Drill or wire chucks are occasionally used on the lathe. These may be of the split-sleeve or sliding-jaw type, or of the form shown in Fig. 161. In this form sleeves of various sizes are used, and the drill or wire is secured by means of the set-screw.

All the above chucks are only capable of use when the work has to be machined concentric or eccentric.

A chuck for machining oval or elliptical work is shown in Fig. 162. It is not exactly the vise which grips the work, but rather the mechanism upon which the vise is mounted, and by means of which the combined rotatory and reciprocating motion of the work is obtained. The chuck consists of an iron or steel body, which is mounted on the nose of the driving spindle, and which carries the slide to which the driving chuck or face-plate is attached. This slide carries two gun-metal or hardened steel segments or slippers which revolve round a former ring which is secured to the front of the headstock. The position of this former ring is adjustable horizontally, as are the slide segments when the slide is vertical. These two adjustments are necessary when the ratio between the two diameters of the oval has to be altered. It should be noticed here that the ovals which are so formed are not perfect ellipses, since they are derived from the circular motion of a point about the centre of rotation; nor is the oval quite symmetrical. The departure from perfect symmetry is, however, in most cases a negligible quantity.

7. Drivers for Wood.

In general, the methods adopted for the driving of wood in lathes differ radically from those which obtain in the case of metal turning, the difference being largely due to the difference in texture of the two substances.

The commonest form of wood-driver is the claw-centre and is shown in Fig. 163. As its name implies, it is socketed in the driving spindle, the two sharp edges being forced into the work. The

axial faces act as the drivers. A slight variation of this is the fork driver, shown in Fig. 164. Such drivers are only suitable for work which can be supported by the loose-headstock centre. For other kinds of work, the flange screw-driver is used. This

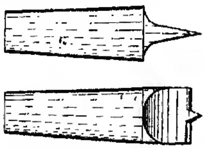


FIG. 163.—Claw-centre driver.

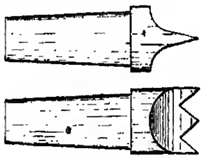


FIG. 164.—Fork driver.

is represented in Fig. 165. The cross-blade driver (Fig. 166) is also suitable for driving wood. Another form of wood-driver is the face-plate, which is provided with small projecting pins for pressing into the wood. Such a form is shown in Fig. 167. A special form of driver is indicated in Fig. 168. It consists of two

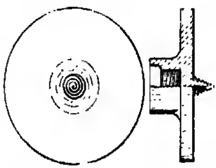


FIG. 165.—Flange-screw driver.

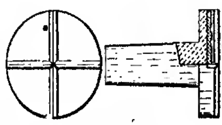


FIG. 166.—Cross-blade driver.

sharp-edged heads, A and B, A having a tapered shank and a driving key, C, whilst B is provided with a centre hole for the loose-headstock centre.

8. STEADIES AND STAYS.

Work which has a comparatively low length-diameter ratio, and which is driven between the centres.

does not usually require any other support than the two centres, unless it is exceptionally heavy. Slender work, however, does need support at intermediate

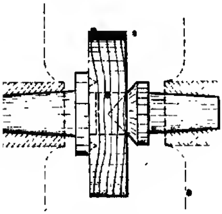


FIG. 167.—Point driver.

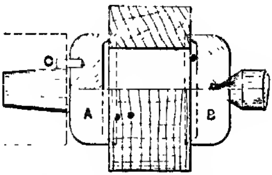


FIG. 168.—Edge driver.

points in order to prevent undue deflection from being produced by the cutting forces.

For this purpose, steady rests or stays are used.

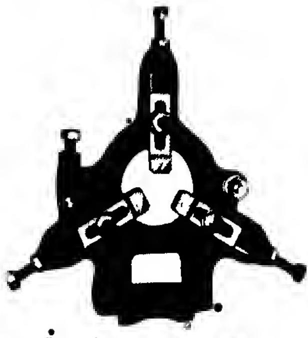


FIG. 169. Stationary steady.

These may be divided into two classes: stationary rests and travelling rests. One form of the former is represented in Fig. 169. It consists of three jaws

which slide in uniformly disposed guides in a frame which is secured to the bed of the lathe. The upper guide is situated in the head which is hinged to the lower part, so that the work may be removed expeditiously. The jaws are screw-adjusted. Variations of this are very common. A very simple form of fixed steady consists of two wood blocks correctly shaped and held in a

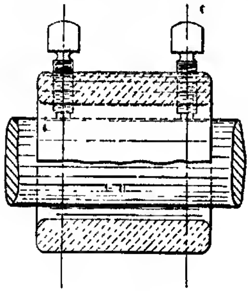


FIG. 170.—Cat-head.

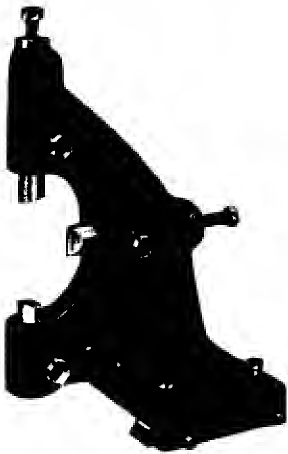


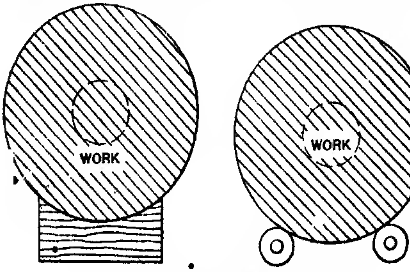
FIG. 171.—Travelling steady.

frame on the bed. The part of the work on which

such a steady is used must be of uniform section. When it is not possible to obtain such a section, an element called a "cat-head" (Fig. 170) is mounted on the work and placed in the steady.

One form of travelling steady is shown in Fig. 171. This travels on the slide-rest immediately behind the tool or tools, the jaws being always in contact with a newly turned surface. Other forms carry only two jaws, or one jaw with two bearing surfaces.

Bearers or supports for very heavy work, such as shafting and gun-tubes, may be of either of the



FIGS. 172 and 173.—Bearer steadies.

forms shown in Figs. 172 and 173, wood blocks being used in the former, and rollers in the latter.

A form of steady which is used when the end of a turned shaft has to be machined (e.g. bored) consists of a circular plate mounted on a frame and pivoted at its centre. Holes of various diameters are formed in the plate at a constant radius from the axis, it being possible to dispose any one of the holes so that its axis coincides with the lathe axis. The plate is, of course, locked in such a position. Parallel or tapered holes may be used in such a plate.

CHAPTER X.

LATHE CUTTING TOOLS.

1. Tool Steels.

All lathe cutting tools, irrespective of the operations which they have to perform, depend, in common with practically all other kinds of cutting tools which have a shearing or abrasive action, for their cutting capabilities upon their hardness. It may be taken as a general rule that, under ordinary conditions of service, a cutting tool (or at least that part of it which is active in the cutting operation) must be harder than the material upon which it has to operate; and to this rule the lathe cutting tool provides no exception.

Now, for many centuries cutting tools of the many various kinds have been made of steel, which is essentially an iron-carbon compound, this substance possessing a property which does not appear to belong to many other than iron compounds, namely, the property of acquiring hardness under suitable conditions of thermal treatment, this hardness being usually greater than that of the majority of substances as they occur in nature. Hence, this metallic compound is eminently suitable for use in lathe cutting tools.

At the present time lathe cutting tools (as well as

the cutting tools used in other machine tools) are made in four different kinds of steel, these being essentially different. They are (1) plain carbon tool steel; (2) self-hardening or air-hardening tool steel; (3) ordinary high-speed tool steel; and (4) superior high-speed tool steel.

1. **Plain Carbon Tool Steel.**—This is the only steel that, practically speaking, lathe cutting tools were made of up to the year 1870. It is steel which contains the following elements within the given percentage proportions:—

Carbon.	Manganese.	Silicon.	Phosphorus.	Sulphur.
1·20 to 1·50	0·10 to 0·30	0·10 to 0·20	0·010 to 0·020	0·015 to 0·030

The carbon, manganese, and silicon are desirable elements and add to the quality of the steel if kept within the above limits, but the phosphorus and sulphur are undesirable and are, therefore, kept as low as is practically possible. Phosphorus produces what is known as "cold-shortness" in the steel (that is, excessive brittleness when cold), whilst sulphur causes "hot-shortness" (that is, brittleness when hot), making the steel more or less unwieldable and unforgable. If the "carbon content," as the carbon percentage is often named, is greater than 1·50 the steel is too hard and brittle for use in turning tools, whilst if it falls much below 1·20 it cannot be made hard enough for service under the conditions obtaining in lathes.

This steel is hardened by raising its temperature to about 800° C. and then quenching in some cooling medium such as water more or less suddenly. The heating may be effected in a coke fire (blacksmith's hearth), gas furnace, salt or lead bath, though in each case care should be taken to prevent the tool from being overheated as this is always likely to ruin it. The steel in this hardened condition is too brittle and not tough enough for satisfactory service; hence it is necessary to reduce the degree of hardness slightly by "tempering" the tool. In the tempering process the temperature of the steel is first raised to about 230° C. and then reduced to the normal temperature of the atmosphere by again quenching in water. In some cases a trace of sulphuric acid is put in the quenching water; in others, salt or brine; in others, lime; whilst in some cases a layer of tallow is placed on the water and through this the tool has to pass, the effect of this being a slight retardation of the quenching process. In any case, the temperature of the quenching water should not be less than 20° C. When steel of this kind is quenched in oil (cotton-seed, rape-seed, or whale oil) the hardness produced is less than when water is used, but the toughness is much greater.

There appears to be a difference of opinion amongst scientific metallurgists as to the precise explanation of the hardening phenomena of steel, though the weight of authority is undoubtedly cast on the side of what has come to be known as the "carbonist" school, whose main principle is that the change in the hardness of the steel is brought about by a change in the properties of the contained

carbon. In the unhardened state steel contains a mechanical mixture of iron and normal carbide of iron, this being known as pearlite, and the constituent carbon as softening carbon. When the temperature of the steel is raised this pearlite is gradually converted into a chemical compound to which the name "hardenite" has been given, the contained carbon being known as hardening carbon. Now the temperature at which this transformation is quite complete is in the neighbourhood of 800° C., and if the steel can be quenched sufficiently rapidly from this temperature the hardenite can be held in the steel. On the other hand, if the cooling is very slow the hardenite eventually becomes the original pearlite. Again, if the steel containing the hardenite is reheated, the return to the pearlite is started until when a temperature of about 300° C. is reached the reversion has been made complete.

In the case of a lathe turning tool, therefore, it is obvious that the cutting power is practically nil when this temperature (which is sometimes referred to as the temperature of stability of the carbon) has been reached, though it is not only due to the rise in temperature that such a tool fails in its work.

2. Self-hardening or Air-hardening Tool Steel.—This in its original form, as made by Mushet in 1870, consisted of a plain carbon steel to which was added a fairly large percentage of tungsten and a small percentage of manganese. The following table gives the ranges of the percentage proportions of the elements contained in this class of tool steel:—

Carbon.	Tungsten.	Manganese.	Chromium.	Silicon.	Phosphorus.	Sulphur.
1·25 to 2·25	4·00 to 10 00	1·50 to 3·50	0·20 to 2·00	0·40 to 0·90	0·010 to 0·020	0·020 to 0·040

The chromium was introduced first as an addition to the manganese, but later it displaced a portion of the latter.

The introduction of tungsten was found to fortify the hardenite so that the temperature at which the latter reverted to pearlite was about 400° C. The addition of chromium increased the fortifying effect of the tungsten.

Tool steels of this type are hardened without quenching or rapid cooling, it being found that if heated to a temperature of 1000° C. and then allowed to cool in a draught of air they are sufficiently hardened. Hence their name.

They were and are still used at practically the same speeds and feeds and depths of cut as plain carbon-steel tools, but on the harder materials.

3. **Ordinary High-speed Tool Steel.**—This is a variation of the self-hardening steel, the variation having reference to the heat treatment in the hardening operation more than to the chemical composition, though this is slightly different as the first table on opposite page indicates.

In some cases the element molybdenum is used in addition to tungsten, but steels of this type are not generally superior to the non-molybdenum steels.

This kind of tool steel is hardened by raising its

Carbon.	Tungsten.	Manganese.	Chromium.	Silicon.	Phosphorus.	Sulphur.
0·50 to 1·00	10·0 to 20·0	0·10 to 0·25	2·5 to 5·0	0·20 to 0·60	0·015 to 0·030	0·020 to 0·040

temperature to 1300° C. in a coke fire or an electric (barium-chloride) furnace, and then rapidly cooling in a strong air blast or heavy oil. Usually, no tempering is required.

A quality known as "red hardness" is possessed by this steel, and by virtue of this property the steel is able to be used in a cutting tool even when it is red hot. In this case the temperature of stability of the carbon is probably about 600° C. This enables the steel to work at much higher speeds and with much heavier cuts than are possible in the case of either of the steels already described.

The metallurgical explanation is, briefly, that the tungsten and chromium fortify the carbon by surrounding it, and so retard the rate of its reversion.

4. **Superior High-speed Tool Steel.**—This is a scientific and experimental development of the above. Its distinguishing feature is the presence of vanadium. Its chemical composition varies greatly, as the following table shows:—

Carbon.	Tungsten.	Manganese.	Chromium.	Vanadium.	Silicon.	Phosphorus.	Sulphur.
0·50 to 0·80	12 to 26	0·10 to 0·25	2·5 to 6·0	0·25 to 2·00	0·10 to 0·15	0·02 to 0·03	0·03 to 0·06

The hardening treatment for this is slightly different from any of the above. The nose is raised to a uniform temperature of 1300° C.; the cutting edge only is then immersed in water at about 25° C. and left until it is black; after which the whole tool is immersed in heavy oil, and allowed to remain therein until it is quite cool.

The temperature of stability of this steel is probably as high as 700° C., since tools made of it will cut when they are a bright red colour.

Cobalt steel is the latest metallurgical invention. It is a tool-steel of the high-speed variety with which is incorporated a percentage of cobalt ranging from 5 to 15. The results of tests made by Prof. Schlesinger, of Charlottenburg, appear to show an amazing superiority of this steel over the ordinary high-speed steels, but experiments made by the author do not indicate the existence of any such huge superiority.

2. Tool Forms.

(*a*) **Wood-turning Tools.**—These are usually hand tools, though there are wood-turning lathes with mechanical movements. The three commonest forms of these tools are represented in Fig. 174. A is a curved-edge tool, or gouge; B and C are two different forms of straight-edge turning chisel.

(*β*) **Hand Metal-turning Tools.**—The principal forms of these are shown in Fig. 175. A and B are brass-turning tools, the manipulation of which does not demand the same power as that of iron and steel-turning tools. A is a square-nosed tool; and B a round-nosed tool. The others are iron and steel-

working tools. C is a square-nosed tool, in the manipulation of which the heel of the tool plays an important part. D is a graver or diamond-pointed tool. This is an exceedingly useful tool, and has two cutting edges. E is a parting tool; and F a side tool.

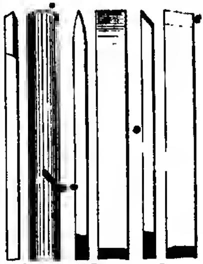


Fig. 174.—Wood-turning tools.

An external hand screw-thread chaser is represented in Fig. 176; and an internal chaser in Fig. 177.

The shanks of all hand tools are inserted into wooden or compressed-paper handles to render their use easier.

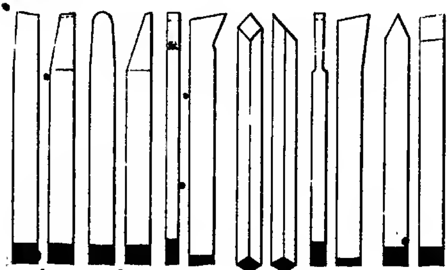
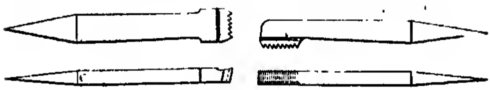


Fig. 175.—Hand metal-turning tools.

For internal work a hooked rest has to be used to support the tool, this rest being placed on the ordinary tool rest, with the handle usually under the arm of the operator.

(γ) **Mechanically-controlled Tools.**—These are of multifarious forms, which differ in shape as widely as they do in regard to the work which they perform. In nearly every case, however, the nose of a tool is



FIGS. 176 and 177.—Screw-thread chasers.

shaped so that the upper face—called the lip—falls back from the cutting edge, whilst the end—known as the flank—falls inward. Such conditions are represented in Fig. 178, which represents a plain

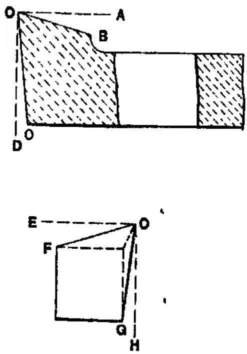


FIG. 178.—Diagram showing angles of tool.

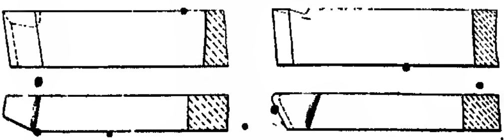
tool—though the same conditions hold in regard to all other tools. The upper view is a side sectional elevation; the lower view a front end elevation. The following definitions of the various angles are usually adopted: AOB, the front rake; COD, the front or

heel clearance; BOC, the front tool angle; BOD, the front cutting angle; EOF, the side rake; GOH, the side clearance; FOG, the side tool angle; and FOH the side cutting angle. These are the angles which are actually ground on the nose of the tool; the angles which obtain in any case during cutting depend, not only on the original angles ground on the nose, but also upon the disposition of the tool with respect to the work, the form of the work, and the feed of the tool per revolution of the work.

For the majority of tools, the principal of the above angles have the following values:—

Metal to be Machined.	Clearance.	Front Rake.	Side Rake.	Tool Angles.
Cast Steel . .	4°-10°	5°-10°	10°-15°	75°-81°
Mild Steel . .	4°-10°	10°-20°	15°-25°	60°-76°
Cast Iron . .	5°-8°	5°-12°	10°-20°	68°-80°
Gun-metal .	5°-8°	0°-5°	0°-5°	77°-85°
Brass . .	5°-8°	0°-5°	0°-5°	77°-85°

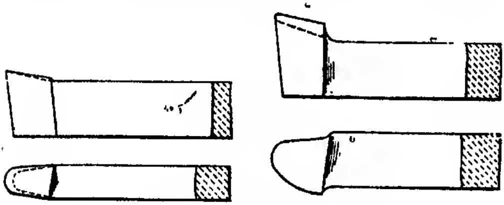
Tools for heavy cutting—that is, roughing cuts—are now made universally of high-speed or self-



FIGS. 179 and 180.—Tools for heavy cutting.

hardening steel—chiefly the former. Figs. 179 to 182 represent four of the many different forms of such tools. The tool shown in Fig. 180 has a longer

cutting edge than any of the others for any given depth of cut, and will last longer, *ceteris paribus*, but it requires more power to drive the work against its resistance. On large tools an original clearance angle of 15° is formed, and this at the cutting edge is reduced



FIGS. 181 and 182.—Tools for heavy cutting.

to 5°-8° in the subsequent grindings. This reduces the amount of stuff which has to be removed at each grinding, though this amount is increased at every subsequent grinding. Sometimes a 10-degree clearance is ground on the tool, and the cutting edge

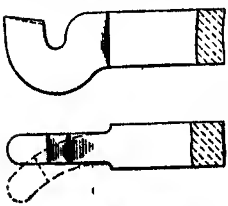


FIG. 183.—Round-nosed tool.

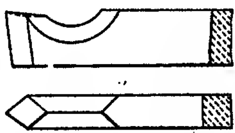


FIG. 184.—Diamond-pointed tool.

raised above the horizontal plane containing the lathe axis.

An ordinary round-nosed crank tool is shown in Fig. 183. This is a very old tool, and was commonly made in plain carbon steel for roughing and semi-

roughing sliding and surfacing cuts. The dotted lines represent a right-hand side tool.

A diamond-pointed tool is indicated in Fig. 184. This can only be used for light cuts. It is better than a tool with a long cutting-edge on brass and other

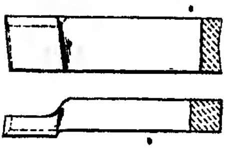


Fig. 185.—Knife tool.

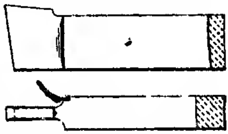


Fig. 186.—Parting tools.

metals of a similar texture, especially if the point is slightly rounded.

A right-hand knife tool is shown in Fig. 185. This is used for end and side facing. The cutting-edge is quite straight, and should be horizontal.

Fig. 186 represents a parting or cutting-off tool.

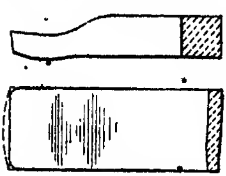


Fig. 187.—Finishing tool.

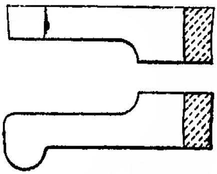


Fig. 188.—Boring tool.

On this tool longitudinal clearance is necessary in addition to the ordinary flank clearances.

One form of finishing tool—for which plain carbon steel is still much used—is shown in Fig. 187. The cutting edge may be quite straight with slightly rounded ends, or slightly curved (as indicated by the dotted lines). A variation of this is the spring

tool, which is cranked upwards, a wood block being inserted between the checks of the crank.

An internal or boring tool is represented in Fig. 188. The nose is turned at an angle of 90° to the shank of the tool. A round cutting edge is shown, though practically any shape may be given to it.

Screw-cutting tools have to be specially shaped. Those for vee-threads (Whitworth or U.S.S.) are vee-shaped, and those for other threads must have a plan section which corresponds to the thread profile. In every case the side clearance on the leading side must be greater than the pitch angle at the bottom of

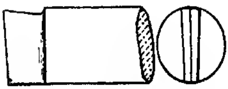


Fig. 189.—Screw-cutting tool.

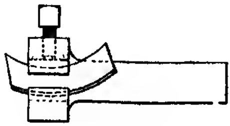
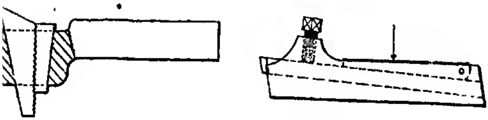


Fig. 190.—Tool holder.

the thread, whilst on the following side it is usual to incline the flank in the same direction just sufficiently to clear the thread. When the pitch of the thread is coarse, and the pitch-angle comparatively great, it is difficult to grind a satisfactory nose on a tool of square or rectangular section, owing to its great inclination, the round-section tool (Fig. 189) is then used. This tool can be twisted about its axis quite easily, and any required inclination of the nose given to it. It is held in a clamp vice or special holder. Other forms of screw-cutting tools are the chaser, the circular formed tool, and the die, which are used on turret and screw machines.

3. Tool Holders.

To reduce the cost of tool-steel, and to reduce the risk of fracture in hardening, it is customary to use tool-holders, which carry high-speed steel inserts. Three forms of tool-holders are shown in Figs. 190-2. The first is designed so that the front rake is fixed; and the second so that the front or heel clearance is fixed. The third is essentially a holder for a screw-cutting tool, it being so designed that the pressure of the clamp or screw on the holder is exerted through the tool, this action tending to prevent slippage of the tool in the holder.



Figs. 191 and 192.—Tool holders.

Practically all turret tools are held in holders, though such are usually of the circular shanked type. Centring tools, cutting-down tools, and hollow mills are so secured.

Forming tools, whether of the circular or shanked type, are usually very accurately and carefully made. Where exact reproduction of shape is essential, it is necessary to work such tools with no rake. This, naturally, impairs their cutting capabilities, but this is a defect which, in this particular case, is of very little moment. Rake is often used on circular forming tools, but these are not used for purposes of exact reproduction, though the shapes that they form are fairly definite.

CHAPTER XI.

LATHE WORK.

1. **Centring Bars.**—The position of the centre of a bar may be located in several ways. A centre-square of one of several forms may be used; a surface gauge or scribing block may be used, with the work resting in a vee-block; compass or hermaphrodite calipers, or odd-legs, may be used; or a bell-centre-punch (Fig. 193) may be used to locate the position of the centre, and to fix it by punching.

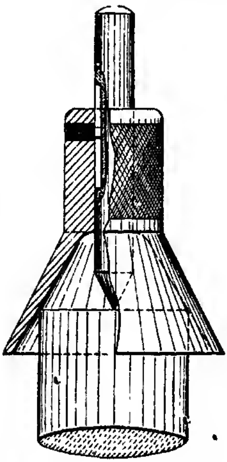


FIG. 193.—Bell centre-punch.

When the work is rough or of medium weight, it is a very common practice to punch the centre holes. It is, however, an antiquated method, its retention only being justified on the grounds of supposed low cost. The effect on the lathe centres cannot be

anything but harmful, whilst accuracy must be an unknown quantity where such a practice prevails The only reasonable method is to drill and countersink the centre holes. Where the work is small and light, the improved form of combined centring and countersinking drill (Fig. 194) may be used, or one of the several variations of this which exist. Where the work is large, the drilling and countersinking have to be performed separately. The centring may be done by hand, in a drilling machine, or in a specially designed centring machine, which may or may not have a bell-chuck for locating the position of the centre at the same time as the centre hole is being drilled and countersunk.

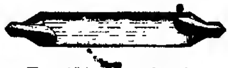


FIG. 194.—Centring drill.

In regard to the position of the centre of work of an irregular section, such as rough forgings, it may be pointed out that the usual practice is to relate this to the highest points in the surface of the work, though, if the forging has been close, it is better, if it is possible, to relate it to the lowest points. If the latter method is adopted, the chances of being able to machine the forging up to size are usually much greater than in the other case.

2. **Forcing Work on Mandrels.**—Mandrels should never be struck directly by the hard steel face of a hammer head, as this tends to deface the ends and damage the centre holes. Where a hammer has to be used, it should have a leather face, or a piece of wood, leather, or fibre should be used between the mandrel and the hammer head. Also, a properly designed mandrel block should be

used, so that the work is not damaged when the mandrel is being removed. It is far better, however, to drive mandrels in and out of work in a mandrel press, in which the forcing pressure is applied gradually and continuously, and not in the form of a blow. There are several forms of mandrel press, the chief being the hand-actuated geared and ungeared types, and the mechanically-actuated type, embodying the principle of the screw or rack.

3. **Screw-cutting.**—In the engine lathe, the necessary regular longitudinal movement is given to the tool from the lead-screw, there being a *positive* gearing connexion between the driving spindle and the lead-screw. When there is no intermediate change-gear box, the sizes of the change-wheels required for the formation of a screw thread can be calculated as follows: let P = the pitch of the lead-screw, and p = the pitch of the screw to be cut. Then—

$$\frac{p}{P} = \frac{\text{Product of Drivers}}{\text{Product of Followers}}$$

The drivers are the wheel on the stud and the second on the quadrant plate; the followers are the first wheel on the quadrant plate and the one on the screw. A list of wheels suitable for different pitches is given in Table II of the Appendix.

Metric threads can be cut fairly accurately from an English lead-screw by employing a converting wheel of 127 teeth. The calculation is as follows: let P = the pitch of the lead-screw, in inches, and m = the pitch of the metric thread, in millimetres. Then—

$$\frac{m}{P} \times \frac{5}{127} = \frac{\text{Product of Drivers}}{\text{Product of Followers}}.$$

Table III of the Appendix gives a list of wheel combinations suitable for the ordinary metric pitches.

Screw threads are formed on other types of lathe either by means of dies or chasers. The former are usually designed so that they have within themselves the guiding power; whilst the movements of the latter are controlled by either master screws or copies or cams.

4. **Taper-turning.**—Short tapers are formed by means of straight-edged tools. These tools may be of the circular or straight-shanked variety, and may be secured in the tool-post or in a circular tool-holder or box as used on turret lathes. The angle between the axis of the lathe and the cutting edges is made equal to one-half of the total or included angle of the taper. The top slide of the compound slide-rest can also be used for short tapers. It is swivelled through an angle equal to one-half of the total angle of the taper, as above.

On American lathes, tapers up to 24 inches in length and an included angle of 10° can be turned by means of the slide-rest taper-turning attachment, which is one of their characteristics. These attachments are graduated to read in "degrees of taper" and also in "inches per foot". The latter graduations are frequently inaccurate, since they are made on the arc of a circle, and not on a tangent thereto. For small tapers, however, the error is inconsiderable.

The set-over loose-headstock method is available for long slender tapers, as well as for short blunt ones,

though its chief province is in connexion with the former. The amount of set-over, i.e., lateral adjustment, which is usually made, is based on the two end diameters, and made equal to one-half of the difference between these. This is not quite correct, the exact theoretical amount being equal to the product of this and the cosine of one-half of the taper angle. Since, however, theoretical conditions never obtain, and the work does not ride evenly on the

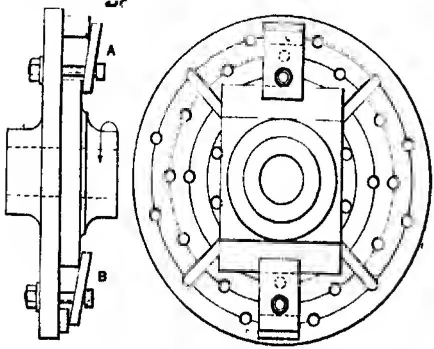


FIG. 195.—Face-plate work.

centres, except when they are of the spherical type, the practical rule is sufficient in all ordinary cases.

Long tapers can also be turned by means of the swivelled top slide, this being used in stages on short lengths of the work. This method requires a large amount of care and preliminary marking-out.

On certain lathes it is possible to turn and bore tapers by combining the sliding and surfacing motions of the slide-rest. Usually, in such cases, the longitudinal movement is derived from the lead-screw,

and the lateral movement from the back-shaft or feed-rod.

An important point to observe in connexion with the general subject of taper-turning is that, unless the cutting edge of the tool is always situated in the plane in which the machine setting is made, the surface will not be truly conical, nor will the amount of taper, as determined by the two end diameters, be equal to that which corresponds to the machine setting. This is a point that must be remembered when circular tools are being set up.

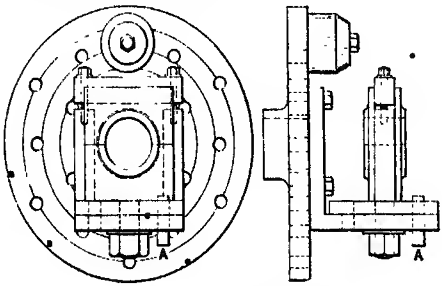


FIG. 196.—Monitor chuck or angle-plate jig.

5. **Face-plate Driving.**—To secure work to face-plates, clamping plates and bolts or hook-bolts are used. The plates should press on the work over a fairly large area, and not on an edge, as is shown in Fig. 195 at A and B. To obtain this condition the packing blocks should be of the same thickness as the work. Also, the holding-down bolts should be placed as near to the work as possible (that is, position A rather than position B should be selected), so that the full benefit of the stresses induced in the bolts is secured.

The use of an angle-plate on a face-plate is indi-

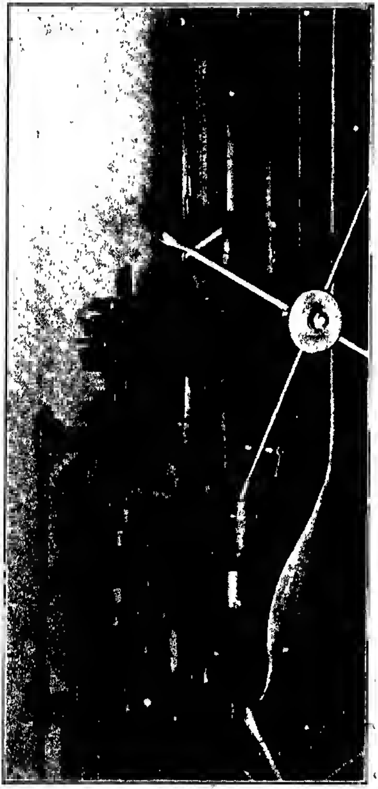


FIG. 197.—Turret-lathe operation.

cated in Fig. 196. Such an arrangement is known as a "monitor chuck," though it is a form of jig o

fixture for repetition work. The case illustrated

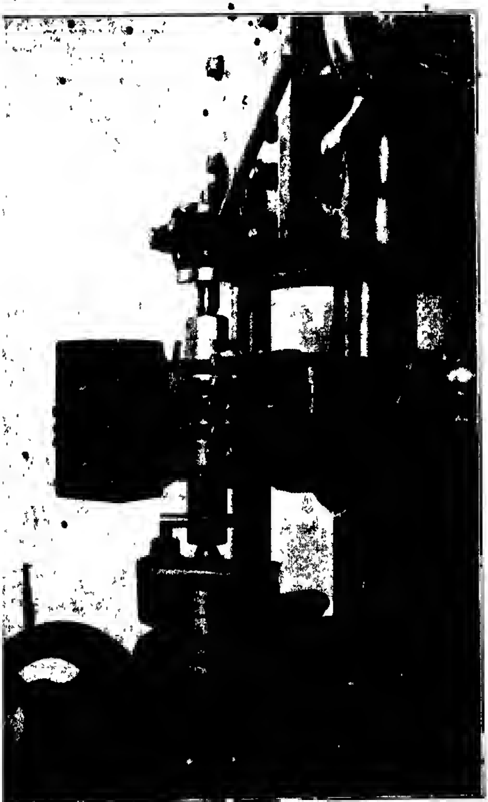


FIG. 198.—Automatic-lathe operation.

is that of locomotive connecting-rod brasses, which can be bored and faced on both sides without removal

from the plate. The brasses are carried in a vice, which is attached to the plate by a large central stud and located in position by a pin A, which can be placed in any one of four pairs of holes in the plate and vice. These holes are spaced equidistantly on a circle so that four positions of the vice are possible.

6. **Turret-lathe Work.**—Fig. 197 illustrates the methods adopted in connexion with the operation of

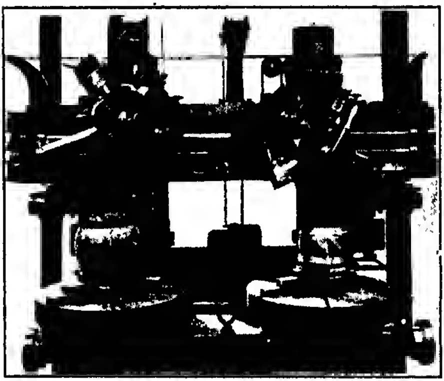


Fig. 199.—Boring and turning-mill operations.

turret lathes. The figure represents chucking practice on a Hartness flat-turret lathe, and shows the use of the automatic thread-chasing attachment.

7. **Automatic-lathe Work.**—Automatic-lathe practice is indicated in Fig. 198. This shows how work, which has been roughed out in a turret lathe, is finished in a Fay automatic lathe. In this case, two pieces are mounted on one arbor with a spacer be-

tween, ten tools are in use simultaneously, and two such machines can be run by one operator.

8. **Boring and Turning-mill Work.**—The use of the boring and turning mill on the smaller classes of work for which it is suitable is demonstrated in Figs. 199 and 200. In all the cases shown a turret tool-slide is employed. In Fig. 199 is shown the machining of a bearing (left hand) and valve liner

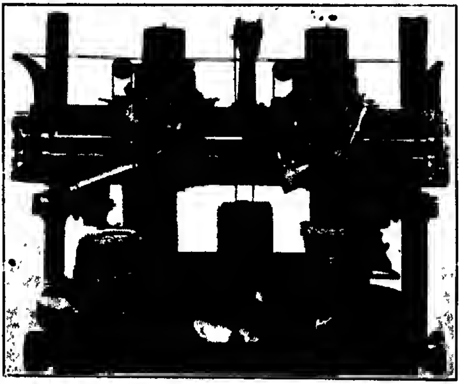


Fig. 200.—Boring and turning-mill operations.

(right hand). The bearing is turned on the top and edge of the flange and bored; it is then reversed in the chuck and the other end likewise treated. The liner is bored and turned at the top end, and then reversed in the chuck for the machining of the other end. The two pieces of work shown in Fig. 200 are a separator base (left hand) and a bearing liner (right hand).

In connexion with the turning and boring of

tapers it is sometimes found impossible to swivel the tool slide through the required angle. In such cases it is customary to combine the horizontal feed with the inclined feed, so as to obtain the required inclination. This combination necessitates the determination of the inclination of the tool-slide. This is accomplished by means of the following formulæ:

$$\sin \delta = \frac{F_h}{F_i} \times \cos \phi \text{ and } \theta = (\phi - \delta),$$

where F_h and F_i are the selected horizontal and inclined feeds; ϕ, the required taper angle formed with respect to the axis; and θ, the required inclination of tho tool-side.

CHAPTER XII.

CUTTING SPEEDS AND FEEDS.

By "cutting speed" is meant the circumferential or surface speed of the work. It is usually measured in either feet per minute or metres per minute. The common practice is to refer this speed to the external circumference or surface of the work, and not that at the bottom of the cut. When the diameter of the work is large in comparison with the depth of cut, the difference between the two speeds is of no moment; but when it is not large, there is a considerable disparity between the two, which ought to be taken into account since the bottom-surface speeds has its effect on the extreme part of the cutting edge

By "feed" is meant the distance the tool travels in the direction of cutting per revolution of the work; though sometimes it is used in another sense, namely, the number of revolutions of the work per inch or centimetre of tool-travel. The second is, of course, the reciprocal of the first.

By "depth of cut" is meant the distance that the tool is entered into the work; it is equal to one-half of the reduction in the diameter of the work. When the operation is a surfacing one, the feed is measured in a direction normal to the axis, and the depth parallel to the axis of the work.

Cutting operations may be divided into two classes: those in connexion with which a large amount of stock has to be removed; and those in which only a small amount has to be removed. The former are roughing-out operations. The latter include, in general, plain finishing, screw-cutting, reaming, drilling, and similar operations.

In the pre-high-speed tool days all cutting tools were made indiscriminately of plain carbon steel, with the exception of those which were used on the very hard and hardened metals, for which the Mushet self-hardening steel was used. The question of cutting speed was not then regarded as of any great importance, and very little attention was paid to the questions of feed, life of the tool, and their influence on the cutting speed. Usually, the determination of the speed was left to the eye of the operator. The speeds which were employed are given as follows:—

On cast steel . . .	12 to 20 ft. per min.
On cast iron . . .	15 to 25 ,,
On mild steel and wrought iron . .	18 to 30 ,,
On brass and gun-metal . .	25 to 50 ,,

The lower speeds were used for roughing cuts with the coarser feeds ($\frac{1}{20}$ in. to $\frac{1}{12}$ in.) and greater depths ($\frac{1}{8}$ in. to $\frac{3}{8}$ in.). For exceptionally heavy cuts, such as 1 inch by $\frac{1}{4}$ inch, still lower speeds were used. The Mushet tools were run at practically the same speeds, but had a much longer life.

At the present time plain carbon-steel is still used for finishing and light cuts generally, though

whether this will always be so is an open question, in view of the great strides that the metallurgical art is making. Reaming and screw-cutting speeds are usually not greater than the above.

The use of high-speed steel is essentially an economic proposition, and many investigators have made researches into the question of its capabilities and possibilities. Since its cost is roughly five times as great as that of the plain carbon steel it is necessary to work it so that its output is at least five times as great as that of the latter. Experiments made by the author have shown conclusively that the economic value of super-high-speed steel is 10 compared with plain carbon steel if all the conditions but the cutting speed are maintained constant. As, however, the output of a lathe roughing tool rises with an increase in the area of the cut and a corresponding reduction in the cutting speed, it follows at once that the maximum economic value of a super-high-speed tool may be greater than 10, though it will not be much greater than 12 or 14.

The cutting speeds and feeds used with high-speed tools show the extraordinary range of 20 to 800 feet per minute. It must be admitted that the upper end of the range is very rarely made use of, the usual speeds adopted lying between 20 and 80 feet per minute.

The allowable speed in any case depends upon several factors, the most important of which are (1) the adopted life of the tool; (2) the feed; (3) the depth of cut; (4) the material to be machined; and (5) the size and shape of the tool. The influence of the first is such that generally the speed is inversely

proportional to about the twelfth root of the life of the tool. The effect of (2) is an inverse two-thirds power effect; that of (3) an inverse one-third power effect. The relation between the cutting speed and, say, the tensile strength of the material is a straight-line one for Siemens-Martin bars and forgings. The allowable cutting speed is raised with an increase in the section of the tool, or with a change in the disposition of the cutting edge so as to increase its effective length."

Another point to observe is that the use of a cooling medium—wrongly called a lubricant—results in an increase in the permissible speed of a high-speed tool. This increase ranges from 25 to 40 per cent. For carbon tools an oil lubricant is often used, though here the cutting action is different from that of a high-speed tool, and a lubricating medium has a well-defined province in connexion with such.

APPENDIX.

Table I.*—*Hendey-Norton Lathe, with Twelve-change Feed-gear Box.*

List of Screw Threads *that can be cut with* Six Change Wheels.

No. of Teeth in Change Wheel on: Stud.	Screw.	No. of Threads per Inch that can be Cut											
168	42	6	5	4 1/2	4	3 1/2	3 1/4	3	2 3/4	2 1/2	2 1/4	2	1 3/4
168	57	8 1/7	6 11/14	6 3/28	5 3/7	4 3/4	4 23/56	4 1/14	3 41/56	3 11/28	3 3/56	2 5/7	2 3/8
168	63	9	7 1/2	6 3/4	6	5 1/4	4 7/8	4 1/2	4 1/8	3 3/4	3 3/8	3	2 5/8
168	69	9 6/7	8 3/14	7 11/28	6 4/7	5 3/4	5 19/56	4 13/14	4 29/56	4 3/28	3 39/56	3 2/7	2 7/8
168 or 84	84 or 42	12	10	9	8	7	6 1/2	6	5 1/2	5	4 1/2	4	3 1/2
69	42	14 14/23	12 4/23	10 22/23	9 17/23	8 12/23	7 21/23	7 7/23	6 16/23	6 2/23	5 11/23	4 20/23	4 6/23
63	42	16	13 1/3	12	10 2/3	9 1/3	8 2/3	8	7 1/3	6 2/3	6	5 1/3	4 2/3
84	57	16 2/7	13 4/7	12 3/14	10 6/7	9 1/2	8 23/28	8 1/7	7 13/28	6 11/14	6 3/28	5 3/7	4 3/4
57	42	17 13/19	14 14/19	13 5/19	11 15/19	10 6/19	9 11/19	8 16/19	8 2/19	7 7/19	6 12/19	5 17/19	5 3/19
84	63	18	15	13 1/2	12	10 1/2	9 3/4	9	8 1/4	7 1/2	6 3/4	6	5 1/4
84	69	19 5/7	16 3/7	14 11/14	13 1/7	11 1/2	10 19/28	9 6/7	9 1/28	8 3/14	7 11/28	6 4/7	5 3/4
69	57	19 19/23	16 12/23	14 20/23	13 5/23	11 13/23	10 17/23	9 21/23	9 2/23	8 6/23	7 10/23	6 14/23	5 18/23
63	57	21 5/7	18 2/21	16 2/7	14 10/21	12 2/3	11 16/21	10 6/7	9 20/21	9 1/21	8 1/7	7 5/21	6 1/3
69	63	21 21/23	18 6/23	16 10/23	14 14/23	12 18/23	11 20/23	10 22/23	10 1/23	9 3/23	8 5/23	7 7/23	6 9/23
42	42	24	20	18	16	14	13	12	11	10	9	8	7
63	69	26 2/7	21 19/21	19 5/7	17 11/21	15 1/3	14 5/21	13 1/7	12 1/21	10 20/21	9 6/7	8 16/21	7 2/3
57	63	26 10/19	22 2/19	19 17/19	17 13/19	15 9/19	14 7/19	13 5/19	12 3/19	11 1/19	9 18/19	8 16/19	7 14/19
57	69	29 1/19	24 4/19	21 15/19	19 7/19	16 18/19	15 14/19	14 10/19	13 6/19	12 2/19	10 17/19	9 13/19	8 9/19
69	84	29 5/23	24 8/23	21 21/23	19 11/23	17 1/23	15 19/23	14 14/23	13 9/23	12 4/23	10 22/23	9 17/23	8 12/23
63	84	32	26 2/3	24	21 1/3	18 2/3	17 1/3	16	14 2/3	13 1/3	12	10 2/3	9 1/3
42	57	32 4/7	[illegible]	24 3/7	21 5/7	19	17 9/14	16 2/7	14 13/14	13 4/7	12 3/14	10 6/7	9 1/2
57	84	35 7/19	29 9/19	26 10/19	23 11/19	20 12/19	19 3/19	17 13/19	16 4/19	14 14/19	13 5/19	11 15/19	10 6/19
42	63	36	30	27	24	21	19 1/2	18	16 1/2	15	13 1/2	12	10 1/2
42	69	39 3/7	32 6/7	29 4/7	26 2/7	23	21 5/14	19 5/7	18 1/14	16 3/7	14 11/14	13 1/7	11 1/2
42 or 84	84 or 168	48	40	36	32	28	26	24	22	20	18	16	14
69	168	58 10/23	48 16/23	43 19/23	38 22/23	34 2/23	31 15/23	29 5/23	26 18/23	24 8/23	21 21/23	19 11/23	17 1/23
63	168	64	53 1/3	48	42 2/3	37 1/3	34 2/3	32	29 1/3	26 2/3	24	21 1/3	18 2/3
57	168	70 14/19	58 18/19	53 1/19	47 3/19	41 5/19	38 6/19	35 7/19	32 8/19	29 9/19	26 10/19	23 11/19	20 12/19
42	168	96	80	72	64	56	52	48	44	40	36	32	28

Table II.—*Change Gear Wheels for Screw-cutting.—English Threads (Without Intermediate Change Gear Box.)*

Screw to be Cut.		Pitch of Lead Screw.															
		1/6 Inch.				1/4 Inch.				1/2 Inch.				1 Inch			
Threads per Inch.	Pitch. in Inches.	Drivers.		Followers.		Drivers.		Followers.		Drivers.		Followers		Drivers.		Followers	
64	0·0156	30	30	80	120	20	30	80	120	—		—		—		—	
60	0·0167	25	50	100	125	20	30	90	100	—		—		—		—	
56	0·0179	20	45	70	120	20	30	70	120	—		—		—		—	
50	0·0200	30	30	60	125	20	40	80	125	20	30	120	125	—		—	
48	0·0208	20	50	100	80	25	30	75	120	20	20	80	120	—		—	
45	0·0222	20	80	50	120	20	40	90	100	20	25	90	125	—		—	
42	0·0238	25	30	70	75	20	30	70	90	20	30	105	120	—		—	
40	0·0250	20	30	40	100	20	55	100	110	20	30	100	120	—		—	
35	0·0286	20	60	70	100	20	40	70	100	20	30	100	105	—		—	
30	0·0333	20		100		20	50	75	100	20	40	100	120	20	25	100	150
28	0·0357	20	30	40	70	20	30	40	105	20	30	70	120	20	20	80	140
26	0·0385	20	60	40	130	20	40	65	80	20	25	65	100	20	30	120	130
25	0·0400	30		125		30	40	75	100	25	30	75	125	20	30	120	125
24	0·0417	25		100		20		120		20	30	60	120	20	20	80	120
22	0·0455	30		110		20		110		20	30	60	110	20	30	110	120

TABLE III.—*Change Gear Wheels for Screw-cutting.—Metric Threads. (Without Intermediate Change Gear Box.)*

Screw to be Cut.		Pitch of Lead Screw.															
		⅙ Inch.				⅕ Inch.				¼ Inch.				½ Inch.			
Threads per Cm.	Pitch. in Mms.	Drivers.		Followers.		Drivers.		Followers.		Drivers.		Followers.		Drivers.		Followers.	
20·00	0·50	30	60	120	127	30	50	120	127	40	30	120	127	20	30	120	127
13·33	0·75	30	60	80	127	30	50	80	127	40	30	80	127	20	30	80	127
10·00	1·00	20	60	40	127	25		127		40	40	80	127	20	40	80	127
8·00	1·25	25	60	40	127	25	50	40	127	45	50	90	127	20	50	80	127
6·67	1·50	45		127		25	60	40	127	50	60	100	127	20	60	80	127
5·71	1·75	60	70	80	127	50	70	80	127	40	70	80	127	20	70	80	127
5·00	2·00	60		127		50		127		35	80	70	127	25	80	100	127
4·44	2·25	20	135	40	127	45	50	40	127	30	90	60	127	25	90	100	127
4·00	2·50	75		127		20	125	40	127	50		127		25		127	
3·64	2·75	30	110	40	127	50	55	40	127	55		127		20	110	80	127
3·33	3·00	90		127		75		127		60		127		30		127	
3·08	3·25	60	65	40	127	50	65	40	127	65		127		20	65	40	127
2·86	3·50	105		127		35	50	20	127	70		127		35		127	
2·67	3·75	60	75	40	127	50	75	40	127	75		127		20	75	40	127
2·50	4·00	120		127		100		127		80		127		40		127	

2·35	4·25	60	85	40	127	50	85	40	127	40	85	40	127	20	85	40	127
2·22	4·50	135		127		45	50	20	127	90		127		45		127	
2·10	4·75	60	95	40	127	50	95	40	127	40	95	40	127	20	95	40	127
2·00	5·00	75	80	20	127	125		127		100		127		50		127	
1·90	5·25	60	105	40	127	50	105	40	127	40	105	40	127	20	105	40	127
1·82	5·50	60	110	40	127	25	110	20	127	110		127		55		127	
1·74	5·75	60	115	40	127	25	115	20	127	40	115	40	127	20	115	40	127
1·67	6·00	75	80	20	127	150		127		120		127		60		127	
1·60	6·25	60	125	40	127	25	125	20	127	125		127		20	125	40	127
1·54	6·50	60	130	40	127	25	130	20	127	130		127		65		127	
1·48	6·75	60	135	40	127	25	135	20	127	135		127		20	135	40	127
1·43	7·00	60	140	40	127	25	140	20	127	140		127		70		127	
1·38	7·25	30	145	20	127	25	145	20	127	145		127		20	145	20	127
1·33	7·50	30	150	20	127	25	150	20	127	150		127		75		127	
1·25	8·00	60	80	20	127	50	80	20	127	40	80	20	127	80		127	

INDEX

H

I

K

L

M

N

O

P

R

S

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